MANAGING TECHNOLOGY TRANSFER IN THE KOREAN MILITARY ESTABLISHMENT

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THESIS

MANAGING TECHNOLOGY TRANSFER
IN THE KOREAN MILITARY ESTABLISHMENT

by

Dae Sun Hong

December 1979

Thesis Advisor: J. W. Creighton

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Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Managing Technology Transfer in the Korean Military Establishment		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis; December 1979
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Dae Sun Hong		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		12. REPORT DATE December 1979
		13. NUMBER OF PAGES 119
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Economic Development
Military Self-sufficiency
Self-reliance in national defense
Technology Transfer

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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Both the economy and defense need advanced technology to maintain their rate of growth and to accomplish the country's utmost goal, self-sufficiency.

By examining the historical background of the Korean economy and national defense, the author's intent is to find causes and

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(Page 1) S/N 0102-014-6601

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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Managing Technology Transfer in the Korean Military Establishment

by

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Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
December 1979

ABSTRACT

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I. INTRODUCTION

A. BACKGROUND OF THE STUDY

Korea, one of the poorest countries in the world until early in the 1960's, has maintained a continuous growth in economy and defense power.

From a position uncomfortably close to the bottom of the international income scale and without the benefit of significant natural resources, Korea embarked on a course of industrial growth that became one of the outstanding success stories in international development [Ref. 1].

The Christian Science Monitor, in the last of a series of articles concerning tomorrow's big powers, speculates that Korea and the other developing countries, Brazil, Mexico, Taiwan, Vietnam, Nigeria, Turkey and Iraq, may emerge as future world powers, based on their economic potential and military strength [Ref. 2].

International economic situations and the international environment in the Korean peninsula will not necessarily be favorable to the future of Korea. To overcome anticipated difficulties, Korea badly needs the support of science and technology in both economic and military areas. In modern society, science and technology are considered much more important than other fields. Modern society could neither have been established nor exist without the contributions of science and technology. Modern science has been developing

since the Industrial Revolution in the 16th and 17th centuries. It has been so accelerated in its rate of development in the 20th century that achievements of science and technology during the past seven or eight decades have been greater than those which had been made prior through the whole of human history.

In Korean history, some original scientific and technological achievements such as the inventions of a metal painting-type and a rain gauge can be found. But most of the scientific and technological knowledge being utilized in Korea today was derived from the Western countries; and also most of this knowledge and technology came to Korea in the form of finished products.

Economic power is the most important force behind any nation's strength, but it cannot be maintained without the backup of science and technology. Modern technology is changing so rapidly that today's new technology will be old by tomorrow. Without securing a high level of original technology and the support of science, it is obvious that one nation might fall behind in international competition.

In the particular case of Korea, rapid expansion of the GNP and exports have been made, and the level of technology also has risen through the past several economic development and implementation plans. But because export of the products by both light and labor-intensive industry is losing its superior position and confronting its limitations, competition with advanced industrial countries is inevitable. This

competition will be in technology through the growth of brain-intensive industries such as mechanical, metallurgical, electrical, and electronics industries which need a heavy industrial base and innovational research and development [Ref. 3].

Korea has achieved remarkable military progress. From the army which was equipped with only rifles about 30 years ago, the Korean military has proudly developed the Air Force, the Navy, and the Army, the sixth largest ground force in the world, equipped with modern jet fighters, guided missile boats, and heavy tanks. Modern technology and sophisticated weapons are also needed to maintain such modern armed forces. For a long time after Korea became independent, Free-World allies provided a large amount of aid to assist her to remain secure and to achieve self-reliance. The United States spent $38.3 billion, including $5.7 billion of Economic Assistance Programs, to maintain Korea's stability from 1946 through 1975, the year most of the grant aids decreased substantially [Ref. 4]. A Military Assistance Grant Aid of $3.8 billion is relatively smaller than the $10.8 billion cost of maintaining U.S. military forces in Korea or the $18.0 billion of estimated Korean War costs to the DOD. Still it was sufficient to hold back North Korea's attack and it also decreased Korea's defense burden so as to allocate that amount of resources to economic development or other sectors. Economic growth and strong national defense are interrelated and both require scientific and technological backup.

"A hundred and forty years after the Battle of Trafalgar, the Normandy landings were a triumph of planning, of skill and improvisation." This was a comment of Dr. Lord Bowden, Principal, the University of Manchester Institute of Science and Technology, on the book, The Challenge of War, written by Guy Hartcup. Dr. Bowden also said, in his foreword to the book, that it was a pity that Mr. Hartcup had not told us more about the remarkable feats of the Russian Army [Ref. 5]. G. I. Pokrowsky, General, Engineering Technical Services, Soviet Army, said in his book, Science and Technology in Contemporary War, that a nation's ability to conduct wars depends on that nation's economic productivity. He quoted Friederich Engels' words as follows: "Nothing depends more upon economic conditions than do armies and navies. Armaments, personnel, organization, tactics, and strategy depend, above all, on the level of production and on the means of communications achieved at a given time."

Regardless of ideology, it is true that a nation mobilizes scientific and technological knowledge as much as possible in order to survive. Needless to say, the effect of the mobilization will be different depending on the strength of the economy and on the skill in organizing the given resources.

Aids from outside, mainly from the U.S., have diminished already, and Korea should achieve its self-reliance in defense as soon as possible. With economic growth, the defense burden competes for scarce resources. The situation requires a somewhat new policy which is different from that of the Grant Aid

era. As the Korean economy should transform its policy from a labor-intensive structure to brain-intensive industry, the defense policy also must be formed with more creative and productive activities rather than consumption-oriented performance.

To repay the taxpayers' investment, the defense authority must concern itself with multi-dimensional ways including traditional civic action programs, training technicians and management, and technology transfer. The multiplier effect of all of these cannot be estimated but obviously it will be a great deal and eventually will achieve the nation's security.

"Technology Transfer" is not a term well-known in the Korean military. But present realities require it more than ever before.

The Korean military authority has been in a favorable environment to achieve technological improvement because Free World allies are willing to help and in-country industries want to have jobs. Continuous research and development, proper stock, regeneration, and transfer of internal and external technology can continue the improvement under such a favorable environment.

To gain a return on the taxpayers' and allies' investment in the security of Korea, self-reliance in defense should be achieved as soon as possible. Self-reliance in defense can be achieved through technological superiority. And by managing technology transfer in an appropriate manner, a great deal of technological improvement could be achieved.

B. OBJECTIVES

There are two objectives to this paper. The first is to provide the reader with an appreciation and understanding of the needs for technology resulting from research and development regarding Korea's extreme goals: economic growth and national defense. The second objective is to develop the reader's understanding of possible efforts and roles of the military authority to transfer the technology into use by private and other pbulic sectors.

C. SCOPE

The scope of this thesis develops and encompasses the following key elements:

1. Problems of Korean economy,
2. Issues of national defense,
3. Need for technological innovations,
4. Need for technology transfer,
5. Nature of technology transfer,
6. Role of Ministry of National Defense in technology transfer,
7. Need for systematic management of military technology transfer,
8. Recommendations.

The primary assumption of this thesis is that the Korean military has never managed technology transfer before. Consequently, this thesis emphasizes the very basic necessity to understand the importance of technology transfer and its systematic management.

D. THESIS CONTENTS

Chapter II discusses the problems and issues of the Korean economy and defense in relation to its growth and technology environment. It is intended to infer an interdependent relationship between economic growth and national defense by studying both the historical background and present problems of the Korean economy. Within the scope of this chapter, the author discusses the Korean Research and Develoment (R&D) environment, establishes goals which must be achieved, and identifies general benefits from technology transfer.

Chapter III describes the performance of advanced nations in technology transfer, studies a theoretical point of view to prevent a workable plan and methodology for initiating tasks of technology transfer in the Korean military establishment.

Chapter IV evaluates the findings of the previous two chapters and makes conclusions, emphasizing the need for systematic management of military technology transfer.

Chapter V presents recommendations.

II. PROBLEMS AND ISSUES OF KOREA

A. HISTORICAL BACKGROUND

Since Korea was opened to the modern world by the signing of the Kanghwa Treaty with the Japanese in 1876, there has been much travail to keep the nation's stability and peculiarity.

The continuous struggle by foreign countries for supremacy of the peninsula harrassed internal development until the end of World War II.

Economic growth in Korea during the colonial period was substantial, averaging an annual rate of three percent [Ref. 6]. Industrialization also proceeded rapidly, but the growth and structural change that took place in Korea during the colonial period were designed to meet Japanese, not Korean, needs. To prepare for World War II, the Japanese developed heavy and chemical industries during the late 1930's, and most of them were owned and operated by Japanese with Japanese technicians dominating key industries [Ref. 7]. Industrialization and growth were not closely related to the traditional Korean economy.

Upon liberation from Japanese colonial rule, Korea fell into economic chaos as well as political struggle. Because the Japanese Empire chose to complement its economy with no regard for Korea's self-sufficiency, Korean exports, after liberation, were thrown into world competition where their

former comparative advantage no longer existed. Transferring from the Yen Bloc to world markets created many serious problems for Korea which was excessively dependent on a specialized form of industrial structure that was no longer appropriate. Such problems were further aggravated by the country's separation into North and South. Agricultural and industrial development of the two regions under the Japanese was highly complementary so that the territorial division raised questions about the long-run economic viability of each part of Korea. Thus, partition left South Korea with a greater population and more productive agricultural land than the North, but without the most important mineral resources and the country's power plants. Light industries were mostly located in the South; heavy and chemical industries in the North. The two newly created countries had contrasting structures of production which could have been strongly complementary [Ref. 8].

Heavy industry which had been producing military goods was dismantled by American ordnance teams in South Korea immediately after the war. Also, deterioration of plants accelerated after the Japanese surrender so that only about half the factories that had operated in 1944 were estimated to be operating in 1946, and they were producing at only 20% of capacity [Ref. 9].

Industrial output was also limited by lack of trained manpower. A 1946 survey of the industrial labor force found that 40% of laborers had no formal education, and over 50%

had attended only primary school. Only one-third of technicians had gone beyond primary school. Lack of technical education, as much as lack of supplies and machinery, has made development of an industrial economy in South Korea difficult [Ref. 10].

For the period of the American Military Government (AMG), 1945-1948, 90% of $400 million in economic aid from the United States to South Korea was in the form of food, fertilizer, clothing, fuel, and other commodities under the name of GARIOA, or Government and Relief in Occupied Areas.

The new Republic, established in the southern part of the country on August 15, 1948, exerted serious efforts to reconstruct the destroyed economy. Consequently, reconstruction requirements were reflected in the Korean program of the Economic Cooperation Administration (ECA) for fiscal 1950. Of the $150 million budget, 80% was to be spent on materials and replacement items and only 20% on expansion of capacity [Ref. 11]. As a result of this economic recovery, in spite of many problems of political instability, agricultural recovery and industrial management, agricultural output and industrial production, which had been abnormally depressed in 1947 and 1948, rose substantially in 1949. This shifted American policy away from relief toward longer-term development aid. A three-year program costing $350 million, administered by the ECA, started with $150 million in fiscal 1950, $110 million of which was to cover the cost of importing fertilizer, food, and industrial raw materials. The rest

was for a three-stage capital development program aimed at increasing coal production first, then electrical power capacity, and finally fertilizer output [Ref. 12].

The favorable trends thus set off in the national economy as evidenced by a record GNP growth of 9.7% in 1949 were brought to an abrupt and total halt when the Korean War broke out in June, 1950. With the North Korean invasion, the South returned to extreme economic disorganization and social chaos. There were tremendous damages to property as well as much loss of lives. About 42 to 44% of the pre-war manufacturing facilities were damaged. Domestic commodity production sharply declined to half its 1949 level by the average production index [Ref. 13]. The total damage inflicted by the three-year war was estimated at $3 billion, and the annual economic growth of the country suffered a 15.5% setback in 1950 and a 6% setback in 1951, gaining only 1% in 1952 [Ref. 14].

After the Korean War, reconstruction of the infrastructure and industrial facilities was emphasized, and then policy emphasis was gradually shifted from reconstruction to price stabilization. In addition to reconstruction and stabilization, considerable proportions of available resources were allocated to the maintenance of strong military forces to forestall any new attack from the North [Ref. 15]. During the post-Korean War period, both the economic and military programs were largely financed and supported by United States and United Nations assistance. The Korean government and the U.S. aid

mission to Korea (Office of Economic Coordinator) made all major economic policy decisions through the Combined Economic Board. The most urgent programs for reconstruction of industrial plants and infrastructures were completed around the middle of 1957, and the money supply was reduced to about 20% in 1957 from 62% in 1955.

As a result of the concentrated effort to rehabilitate the war-devastated country, in spite of the heavy burden of maintaining large armed forces, real GNP grew steadily during the period 1954-1957.

In contrast to the previous period, economic growth declined during the period 1958-1960. Social and political chaos and the gradual reduction of foreign aid were the main reasons for the decline. And once again, Korean politics, social and economic disorder swayed the whole of South Korea by student revolution and military coup.

Annual Growth Rate of Major Sectors
1954 to 1960
(1970 Constant Prices)

YEAR	GNP	AGRICULTURE, FORESTRY, & FISHING	MINING AND MANUFACTURING	SOCIAL OVERHEAD CAPITAL AND SERVICE
1954	5.5%	7.6%	11.2%	2.5%
1955	5.4%	2.6%	21.6%	5.7%
1956	0.4%	-5.9%	16.2%	4.0%
1957	7.7%	9.1%	4.7%	5.8%
1958	5.2%	6.2%	8.2%	3.5%
1959	3.9%	-1.2%	9.4%	7.5%
1960	1.9%	-1.3%	10.4%	2.8%

Source: Bank of Korea, Economic Statistics Yearbook, 1973 Seoul, Korea.

TABLE I

The Korean economy has been managed as an integral and vital part of a garrison state since 1961. Beginning with the military government, Korean economic policy clearly shifted from the previous emphasis on reconstruction and stabilization to a program of growth maximization through industrialization.

From 1961 to 1976, the government successfully established First, Second, and Third Five-Year Economic Plans (1962-1966, 1967-1971, 1972-1976), and since 1977, the Fourth Plan is in progress.

The First Five-Year Plan (1962-1966) set forth three major sectors to be developed: to build an industrial base principally through increased energy production, attainment of self-sufficiency in food grain production, and development of industries to supply goods previously imported [Ref. 16].

The gross national product grew at an accelerating rate, with an average annual increase of about 8%. The population grew less than had been anticipated so that the GNP per capita actually increased from $87 (U.S.) to $126 (U.S.) in 1962 to $250 million (U.S.) in 1966. This export level was nearly double the goal level.

The most important achievement in economic development under the first plan was the growth of mining and manufacturing at an average annual rate of 14.1%. The growth in social overhead, capital and services was relatively high, 8.3%; and agriculture (including forestry and fisheries) reached only 5.1% in its annual growth rate.

The Second Five-Year Plan (1967-1971) was virtually the same as the first one. But it was essentially a medium-term plan as the next stage in meeting long-range goals. The basic objective of the Second Plan was to promote the modernization of the industrial structure and build the foundations for a self-supporting economy. Targets for this objective included attainment of food self-sufficiency, investment in chemicals, machinery, and iron and steel industries, and a substantial increase in national income. Special focus of the targets was on increased farm productivity and income through diversification of farming. Key strategies for achieving these targets were rapid export expansion, increased capital mobilization, efficient manpower utilization, and continued financial stability [Ref. 17].

The most important change embodied in the Second Five-Year Plan was the expansion of the public sector. One possible reason for expanding the public sector would be to increase investment in social overhead capital, which generally requires public outlays for health, education, housing, urban and regional planning, and the development of science and technology. Diminishing reliance on foreign saving also reflects a great change of characteristics of the economy during the Second Five-Year Plan. Domestic saving rose to 15.6% of GNP after averaging only 7.4% in the First Five-Year Plan period [Ref. 18].

The Second plan, like the First, surpassed expectations by the end of the terminal year. GNP grew annually and

The Results of Economic Growth by the First Five-Year Economic Development Plan

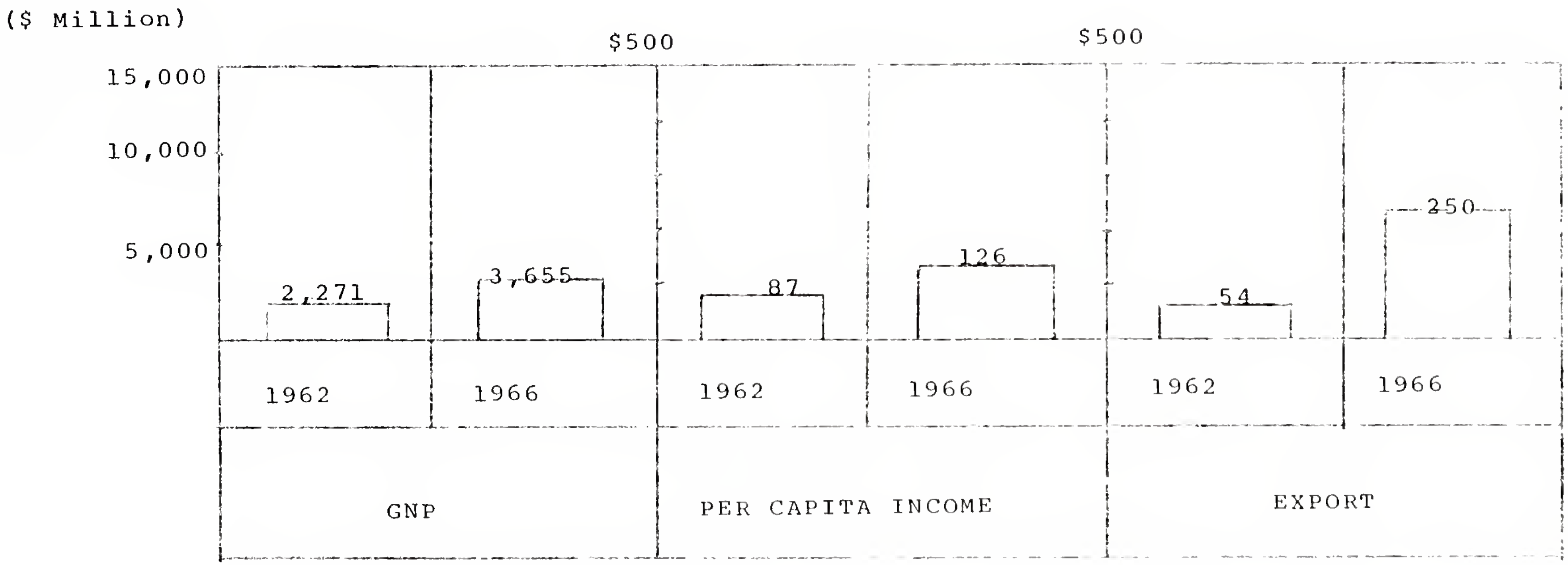

Figure 1: First Five-Year Plan

Source : EPB, Major Statistics of Korean Economy 1977.(Ref.11)

ANNUAL GROWTH RATE OF MAJOR SECTIONS
(AS CUMULATIVE GROWTH RATE, IN 1970 CONSTANT MARKET PRICES)

YEAR	GNP	AGRICULTURE, FORESTRY, & FISHERIES	MINING AND MANUFACTURE	SOCIAL OVERHEAD, CAPITAL, AND SERVICES
1961	4.8	11.9	3.6	- 1.1
1962	3.1	- 5.8	14.1	8.9
1963	8.8	8.1	15.7	7.4
1964	8.6	15.5	6.9	3.0
1965	6.1	- 1.9	18.7	9.9
1966	12.4	10.8	15.6	12.6
1967	7.8	- 5.0	21.6	13.8
1968	12.6	2.4	24.8	15.4
1969	15.0	12.5	19.9	14.6
1970	7.9	- 0.9	18.2	8.9
1971	9.2	3.3	16.9	8.9
1972	7.0	1.7	15.0	5.8
1973	16.7	3.6	30.4	14.6
1974	8.7	5.8	17.0	4.9
1975	8.3	7.1	12.9	5.8
1976	15.3	8.3	25.1	11.3
AVERAGE				
1962-66	7.7	5.1	14.1	8.3
1967-71	10.5	2.3	20.2	12.3
1972-76	11.0	5.3	19.9	8.4
1962-76	9.7	4.2	18.1	8.7

Source: EPB, Major Statistics of Korean Economy, 1977 [Ref. 11].

TABLE II

recorded an average rate of 10.5% in real terms. Per capita GNP doubled. Mining and manufacturing increased 20% per annum; commodity exports advanced from $335 million in 1967 to $1,132 million in 1971.

The Third Five-Year Development Plan can be characterized by its attempt to promote a "balanced economy" by "expanding regional development," "developing and improving life in rural areas," and "improving the quality of the life of workers" [Ref. 19].

These goals are sufficiently vague but suggest a shift in emphasis from building an industrial base and modernizing the industrial structure to rural development and redistributive programs. Prominently, the Third Five-Year Plan targets include achievement of self-sufficiency in food grains, raising of commodity exports to $3.5 billion by 1976, construction of heavy and chemical industries, and promotion of "balanced regional development" [Ref. 20].

At the end of this plan, the nation achieved an annual average growth of GNP of 11% in real terms which exceeded by 2.4% the plan's target. The per capita GNP increased from $293 in 1972 to $698 in 1976, more than four times the target amount. The main contributors to rapid growth were mining-manufacturing which increased an average annual 20% and exports with an average annual growth of 31%.

The major goals of the Fourth Five-Year Plan (1977-1981) are, in essence, to achieve a further shift in the economic structure, stressing labor-intensive manufacturing, especially

The Results of Economic Growth by the Second Five-Year Economic Development Plan

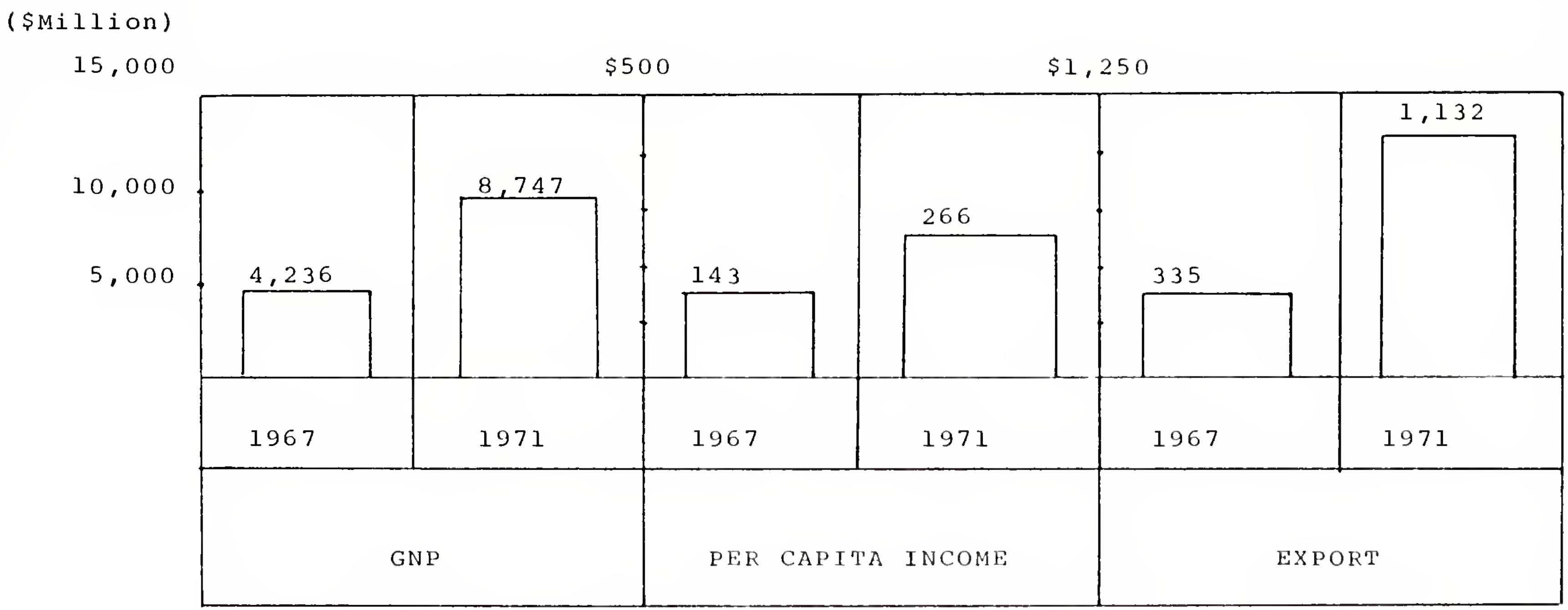

Figure 2 : Second Five-Year Plan
Source : EPB, Major Statistics of Korean Economy, 1977. (Ref.11)

machinery and electronics; to sustain export growth and strengthen the balance of payments; and to improve the distribution of the benefit of growth by maintaining the growth of employment and broadening the availability of essential services, including health and sanitation, housing and electricity.

The targets for these goals are to expand GNP at 9.2% annually, to increase per capita GNP to $1,512, to increase mining and manufacturing at 14.2% per annum, the agricultural sector (including forestry and fishery) at 4%, and social overhead capital and other services at 7.6%, so as to account for 40.9%, 18.5% and 40.6%, respectively, of the GNP in 1981. Commodity exports will increase at 16% and imports at 12% per annum to provide a positive balance by 1979. Domestic savings are expected to rise rapidly from 8% of the GNP in 1975 to 26.1% in 1981. During the plan period, 92% of gross investment will be financed by domestic savings which will constitute 100% of gross investment by 1981.

The thrust of the Fourth Five-Year Economic Plan is to effect a shift in emphasis from light to heavy industry, and especially to those skill-intensive heavy industries of machine-making, shipbuilding and electronics. The aim is to increase exports while at the same time decreasing imports. The share of heavy and chemical industries to total manufacturing output will increase from 42.4% in 1975 to 49.5% in 1981 while the share of electronics, machinery and

The Results of Economic Growth by the Third Five-Year Economic Development Plan

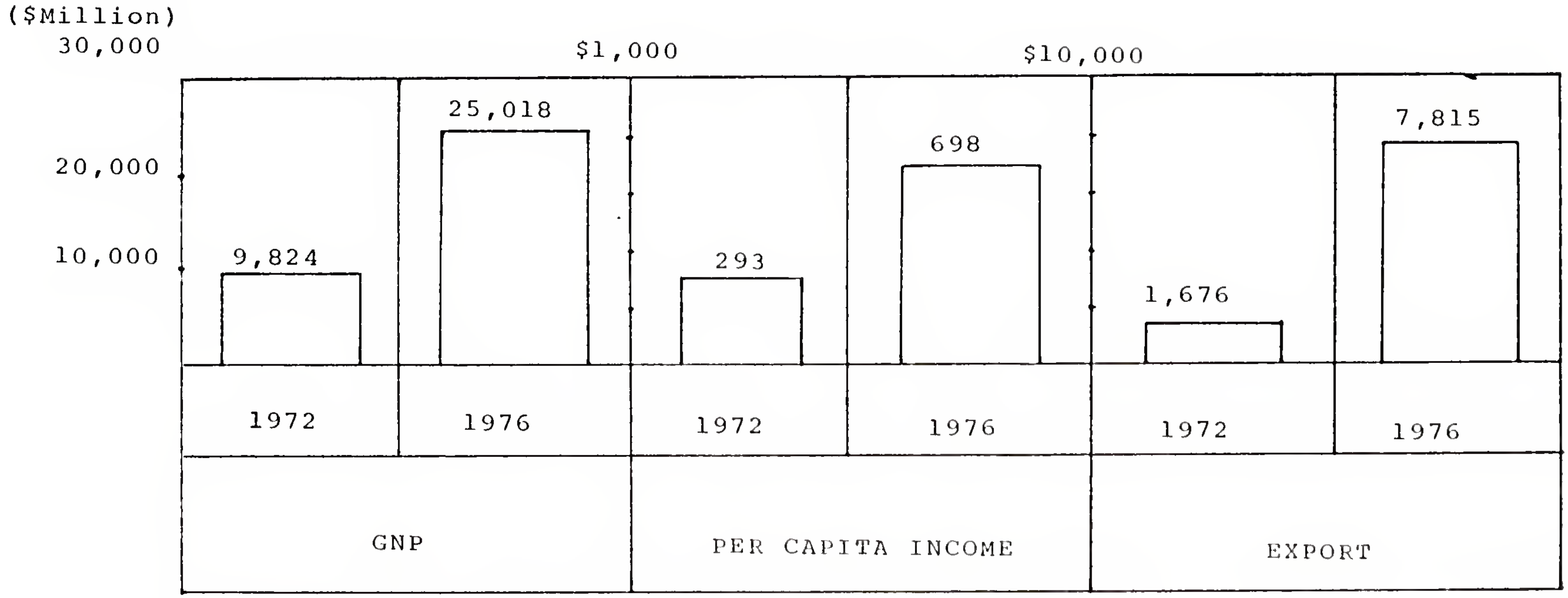

Figure 3 : Third Five-Year Plan
Source : EPB, Major Statistics of Korean Economy, 1977.(Ref.11)

Trend of Economic Growth Rate

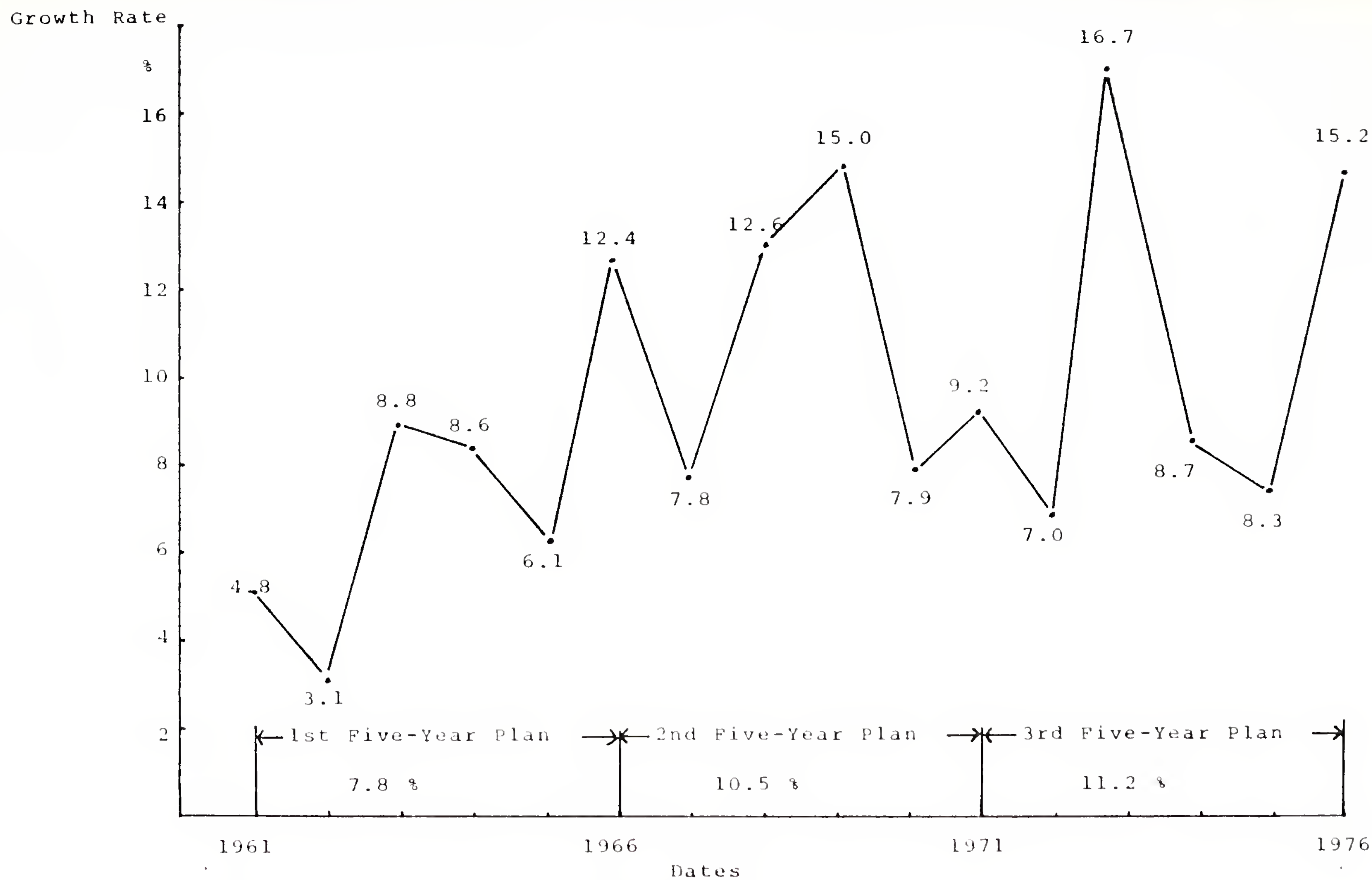

Figure 4 : Trend of Economic Growth Rate
Source : EPB, Major Statistics of Korean Economy, 1977.(Ref.11)

shipbuilding will increase from 14.8% to 24.2%. Due to its key role in defense and in the promotion of exports and the reduction of imports needed to balance the budget, major emphasis of the Fourth Five-Year Development Plan will be on the growth and modernization of the machine industry. The aim for 1981 is to be 70% self-sufficient in machinery as opposed to 50% in 1975.

Shipbuilding capacity would be expected to grow from 2,600,000 gross tons in 1976 to 4,250,000 gross tons in 1981. The electronics industry has grown faster than any other industry in Korea during the past several years and is being developed as one of the major export industries of the future. It produced $1,400 million worth of goods in 1976, and output is expected to reach $2,717 million by 1981, $1,700 million of which will be exported. Steel production is the key to the development of all other heavy industries. While Korea invented the world's first iron-clad ship in the 16th century and the first metal type some 750 years ago, a modern steel industry did not come into being until the 20th century. Korean industry was seriously hampered by a lack of iorn and steel until 1973. As of June 1976, annual production of steel had risen to 4,600,000 tons, and Korea now ranks among the top 20 countries in the world in steel production. Among the other sectors of economic structure, the authomobile industry, chemical industry, power sources, textiles and consumer goods, agriculture, and fisheries have a readily foreseeable future to fulfill domestic demand.

MAGNITUDE AND GROWTH RATE OF THE ECONOMY

	Unit	1976 (A)	1981 (B)	B/A	1977-1981 Average Annual Rate of Growth (%)
GNP	Bil. won in 1975 prices	12,109	16,214	1.3	9.2
	Bil. dollars in 1975 prices	25.0	33.5	1.3	9.2
	Bil. dollars in current prices	25.0	58.7		
Population	Million persons	35.9	38.8	1.1	1.6
Per Capita GNP	Thous. won in 1975 prices	337	418	1.2	7.6
	Thous. won in current prices	337	732		
	Current dollars	698	1,512		

Source: The Fourth Five-Year Economic Development Plan 1977-1981, ROK [Ref. 21].

TABLE III

COMPARISON OF INDUSTRIAL STRUCTURE (IN PERCENT)

	1975	1981
Primary Industry	25.7	19.6
Secondary Industry	29.1	57.5
(Manufacturing)	(28.0)	(36.3)
Tertiary Industry	45.2	42.9

Source: Industry in Korea 1976, the Korean Development Bank [Ref. 21].

TABLE IV

To implement such an ambitious plan, financial and technological support is needed. The Korean government plans to provide the overall investment requirement by domestic savings by 1981. Besides competent planning and proven ability in economic development, Korea offers a number of incentives to potential foreign investors. Government policy is to encourage and protect foreign investments, especially those which tend to contribute to economic development, an improved balance of payments position or the introduction of essential advanced technology [Ref. 21].

To solve technological problems, the Korean government has founded research and education institutes such as the Korea Institute of Science and Technology (KIST), the Office of Atomic Energy (OAE), the Korea Advanced Institute of Science (KAIS), and the Korea Scientific and Technology Information Center (KSTIC). These institutes and offices are working on technological problems related to industrial development, researching the peaceful use of atomic energy for industry, medicine and agriculture; providing graduate education in science and engineering to fill the need for scientists well trained in technology relevant to the problems of developing nations and to conduct research of interest to Korean industries; and collecting and disseminating information for scientific research and industrial development.

According to the Economic Planning Board (EPB), the Korean government will increase its spending for research and development from 0.5% of the GNP in 1975 to 1% in 1981.

INVESTMENT AND FINANCE PLAN IN ECONOMIC DEVELOPMENT

(At 1975 Prices in Billion Won)

	1975 (A)	1981 (B)	B/A	Total for 1977-81 Amount	Percent
Gross Investment	2,478.4	4,219.9	1.7	18,008.1	100.0
(Ratio to GNP)	(27.3)	(26.0)		(26.2)	
Domestic Savings	1,635.9	4,231.0	2.6	16,645.1	92.4
(Ratio to GNP)	(18.0)	(26.1)		(24.2)	
Marginal Propensity to Save)	(33.1)	(37.5)		(35.3)	
Foreign Savings	1,023.0	- 11.1		1,363.0	7.6
(Ratio to GNP)	(11.3)	(- 0.1)		(2.0)	
(In Million Dollars)	(2,113.0)	(- 23.0)		(2,816.0)	
Statistical Discrepancy	- 180.5	-		-	
(Ratio to GNP)	(- 2.1)	(-)		(-)	

Source: The Fourth Five-Year Economic Development Plan, 1977-1981, ROK [Ref. 21].

TABLE V

Also a series of plans to develop specific sorts of industrial technology has been established. This plan includes activating specialized research institutes: the Mechanical and Metallurgical Research Institute, the Korea Institute of Shipbuilding and Oceanography, the Chemical Research Institute, the Electrical Machinery Research and Testing Institute, and the Korea Standards Research Institute.

B. PROBLEMS OF KOREAN ECONOMY

Laissez-faire may be a major issue of debate in the Korean economy. It is not a problem related only to Korea. Today's trend is to prefer a policy of mixed economy. To a greater or lesser degree, the governments of all nations are controlling their economies because growth may be affected or even halted by internal and external political problems. Korea is one of the countries which have the worst collateral conditions for economic growth in this sense. Armed confrontation with the North has been an ever-present threat since the Koren War while the potential for an internal uprising appears to have grown in recent years. In addition, the future pattern of development is likely to be influenced by imbalance which has resulted from rapid growth. Any meaningful attempt to regain balance is likely to reduce the future growth rate because greater balance requires comparatively inefficient resource allocation. Besides these political and balance problems, the rate and pattern of Korea's

INVESTMENT PLAN IN SCIENCE AND TECHNOLOGY

(In 1975 Prices Billion Won)

	1975	1981	1977-1981
Gross National Product (A)	9,080.3	16,214.3	
Investment in Science & Technology (B)	48.9 (100.0%)	160.5 (100.0%)	566.0
Government	34.7 (71.0%)	68.8 (42.9%)	294.2
Private	14.2 (29.0%)	91.7 (57.1%)	271.8
Ratio of Investment in Science & Technology to GNP (B/A)	(0.54%)	(1.0%)	

Source: The Fourth Five-Year Economic Development Plan 1977-1981. ROK.

TABLE VI

economic growth during the next several decades are likely to depend upon the international economic situation and the retention of a comparative advantage in labor-intensive manufacturers or, possibly, the development of new types of comparative advantage.

The international economic situation is going to be unfavorable for growth of the Korean economy. Global recession, the oil embargo or increase in price, and raw materials shortages not only restricted Korea's export expansion but also led to deterioration in terms of trade and created difficulties in borrowing to cover unusually large balance-of-payments deficits. The other challenge to the Korean economy is the trend of the Open-Door Policy of the People's Republic of China, which may be a great threat to Korea's staple export commodities produced by labor-intensive light industries. Chinese labor-intensive commodities, when grafted to the capital and technology of Japan and Western countries, have a powerful growth potential. The reason for this is that economic understanding between China and Japan or Western countries is coincident. For example, Japan would like to transfer to China labor-intensive industries, especially shipbuilding, steel and iron, textile, fertilizer, electrical appliances, and plywood, which had led to the high growth rate of the Japanese economy and now have rapidly declined due to the impact of increases in wages and yen value. In contrast, those industries which are declining in Japan are industries which China would now like to

encourage. This Chinese Open-Door Policy and unfavorable situations of world economy are factors that stimulate Korean industries to improve their structure by importing skill-intensive production methods, an accumulation of technology, and industrialization of heavy and chemical products.

On the other hand, the Korean economy is standing at a structural transferring point in its internal growth environment. A structural transferring point means that new driving forces should be developed because the high rate of growth creates many drains on the economy of the nation. The requirements of the people are diversified so that implementation of a growth policy is complicated; consequently, multidimensional policies and goals must be made congruently.

The Korean economy is now experiencing growth restrictions characteristic of a mature economy. There are also structural problems to be solved to overcome the restrictions.

Exports have had advantages in low-wage competition so far. But such advantages are diminishing gradually as internal wages are increasing rapidly and externally import restrictions for labor-intensive commodities are increasing. Industry's capital accumulation is a problem because so far Korean industries have accumulated capital by high price rather than productivity. The industries made profits not by high productivity which is caused by raising the level of technology to produce commodities of high quality at low cost and in great quantity.

They made profits by paying low wages, cheap interest rates, reduction of taxes, and by keeping prices high under a protection policy. But the current situation is likely to allow no more privileges to those industries.

So the industries should change their production method to a labor-saving type and restructure their system to capital and skill-intensive, heavy and chemical industries. But because this requirement of structural innovation arises so rapidly, a supply of internal capital and an accumulation of technology are required. Structural change urgently requires a supply of capital and the development of advanced technology and management manpower [Ref. 22].

Capital and technology can be the key to solve other problems such as price stability, monetary policy, balance-of-payment, balance development, welfare, and redistribution as well as structural innovation of industries. In the scope of this thesis, capital problems are not discussed, and only technology-related aspects are presented.

The number of scientists and engineers who are associated with research and development in Korea is 12,800 at present. This number shows a great difference from the 1,233,000 in Russia, 526,000 in the U.S., 396,000 in Japan, and 100,000 in West Germany. This shortage will be understandable when given as the ratio per 1,000 population. The ratio in Korea is 0.35, 4.9 in Russia, 2.5 in the U.S., 2.3 in Japan, and 1.8 in West Germany. To increase this ratio to one person per every 1,000 population, Korea needs about 40,000 scientists

and engineers by 1991, and about 90,000 of them to increase the ratio to two. To secure this number of scientists and engineers, an increase in quantity of four to eight times will be necessary. It will be very difficult to achieve this goal without an epochal policy support.

Investment in research and development in Korea was 123 billion won (254 million U.S. dollars) in 1977. This figures shows a tremendous increase over the 15 billion won in 1971, and a 76% increase over the 70 billion won in 1976.

This increase indicates that Korea's interest in science and technology is rising; however, it is too small an amount to compare with those of advanced nations.

The U.S. is overwhelming in the amount it invests in research and development for science and technology; the figure reached $32 billion in 1974. Russia spent $24 billion for the same purpose in 1975, Japan $9.3 billion, and West Germany $7.2 billion.

The GNP ratio of these investments to R&D by each nation is 4.5% in Russia, 2.3% in West Germany, 2.28% in the U.S., 2.1% in England, 1.76% in Japan, 1.7% in France, and 0.72% in Korea.

Fortunately, the Korean government had established a long-term science and technology development plan which indicated that the proportion of investment to the Science and Technology plan would be increased at 1.0% of GNP by 1981, 2.0% in 1986, and 2.5% by 1991 [Ref. 23].

Private enterprises have invested too little to develop new products or raise the quality of products. Research and development expenditures of Korean private interprises were under one percent of their sales revenue. For example, electronics and electrical industries in Korea spent $4.2 million for research and development in 1977, representing 0.78% of sales revenue.

In the case of Japan and the U.S., Hitachi's research and development expenditures amount to $207 million, representing 5.4% of its sales revenue. Sony spent 4.5% for the same purpose, Zenith 3.5%, G.E. 2.5%, and Hewlett-Packard's research and development expenditures amounted to $154 million in 1978, which was 9% of its sales revenue [Ref. 24].

Private enterprises now have recognized the lack of technology and the unfavorable international economic situation. To catch up technologically, they have greatly enhanced their basic activities recently. These activities were initiated by private foundations and universities so that coordination between industry and science could be attempted [Ref. 25].

Joint research activities with advanced nations are also being undertaken in Korea. These joint research efforts are meaningful in two aspects. The first is that the Korean scientific society can overcome its backwardness in research capability and experience. The second is to transfer technology to the Third World. The reasons that Korea is

charged with this research are: first, Korea has a relatively good research capability among the developing countries; second, resulting technology, if it is adequate for the Korean environment, can be easily transferred to the Third World.

Technology developed in advanced nations is difficult to transplant because the research level is so high in advanced nations that few scientists in those countries have an interest in appropriate technology for the developing countries. The attempt to transfer advanced technology to the developing countries has failed in the past due to environmental differences and lack of the capacity to receive it. So the movement to develop and transfer appropriate technology or intermediate technology, which is suitable for the environment of developing nations, is coming about.

Through joint research with the National Science Foundation (NSF, U.S.), the German Research Council (DFG, Germany), and the German Technology Development Office (GTE, Germany), Korea plays a role of stepping stone or gatekeeper for technology transfer between advanced and backward nations [Ref. 26].

Increasing funds, enhancing internal activities, and enforcing joint research for science and technology are the key factors for research and development programs to progress so that they eventually contribute to the nation's economic growth.

Dr. Jong-One Choi, Minister of Science and Technology, stated that science is to be not only for scientists but also

INVESTMENT IN SCIENCE AND TECHNOLOGY IN 1977

COUNTRY	FUND		PERSONNEL	
	Million Dollar	Ratio per GNP	Thousand	Ratio per Population of 1,000
England	1,310	2.10	77	1.4
West Germany	7,256	2.30	100	1.8
France	4,791	1.70	65	1.1
Italy	1,410	0.93	34	0.6
Poland	11,103	2.80	101	2.1
Netherlands	1,452	2.05	23	1.7
India	256	0.42	97	0.16
Russia	24,120	4.50	1,223	4.9
Korea (South)	224	0.72	13	0.35
Japan	9,351	1.76	396	2.3
U.S.	32,322	2.28	526	2.5
Hungary	1,585	3.5	23	2.1
Czechoslovakia	2,840	3.9	45	3.0
Yugoslavia	193	0.8	17	0.8

Source: The Dong-A Ilbo, October 13, 1979, Seoul, Korea.

TABLE VII

for national economic development and the people's welfare. This statement encourages people and suggests many policy changes in science and technology. Some problems are anticipated, however, in implementing plans and programs successfully.

The first problem anticipated is lack of personnel who are or will be associated with research and development at the present or in the future. The second problem is lack of technology transfer activities.

About 40% of research personnel in Korea work for universities while 30% are in industry and another 30% in research institutes. In contrast, 73% of available research funds were spent by research institutes in 1977, and only 3% of those funds were allocated to universities.

It is necessary to increase both the number of research personnel and the amount of research funding to meet the requirements of the future.

Universities are the only means to prepare qualified personnel to start research work in society. Universities must be provided with appropriate funding so as to train the personnel who can work in the research field in the future.

Appropriate allocation of funds among institutes, universities, and industries will also aid in organizing scientific personnel.

Without this organization, technology transfer is not to be expected. Korean industries suffered many problems

caused by lack of technology transfer activities. The Korean government commissioned the Elison Machinery Production Technology Support Team to investigate Korean machinery industries in October 1978. The Elison Project team pointed out that a considerable portion of the machinery and technology which Korean machinery industries had imported from overseas is incomplete or backward. The number of items of imported technology in Korea is 1,040 as of June 1978. Expenditures for this technology amounted to $230 million. This technology imported five items in 1962, 82 in 1972, 109 in 1976, and 170 items in 1977. According to the investigation of the Korean Institute for Science and Technology, 36.5% of this imported technology was backward and had been developed before 1955; only 14% of the items were new technology, developed after 1966. Thirty percent of these contracts were under condition of export restriction of products, and almost 80% were contracted in conditions of re-export restriction of this imported technology. The consequences of these backward technology imports were bad. Only 28% of this imported technology could perform at planned productivity while 36% reached less than 50% of planned productivity [Ref. 27]. These serious results could be eliminated or at least reduced by information exchange or strong government control. Of course, there may be other reasons for these results, but those other reasons can hardly exist in the new environment as mentioned previously.

At this time when funds are increasing, internal activities are improving, and international joint activities are beginning for all research and development in science and technology areas, organizing well for technology transfer is the last step to be taken to maximize effectiveness for all research and development effort.

C. THE IMPACT OF NATIONAL DEFENSE ON ECONOMY

The Korean War and the ensuing confrontation with a hostile power north of the 38th parallel led to restricted consumption and for the most part distributive issues in pushing for rapid growth were ignored. However, confrontation has had more direct economic consequences. Korea has been a garrison state since 1953 with a military establishment of over 600,000 men and 20 to 25% of the government budget, or about 4% of the GNP, allocated to defense expenditures [Ref. 28].

Accordingly, as Korea's economy improves, its fiscal dependence on others decreases. By 1980, it is estimated that Korea will be paying more than 95% of its defense bill.

To achieve military self-sufficiency based on strong economic achievement by 1980 is Korea's defense goal. To reach this goal, the defense burden and the percentage of the GNP being funneled into the defense sector of the economy should almost double -- from 3.5 or 4% to 7.5%. In the event that assistance or aid from outside actually dries up, the Korean government has imposed a 15% rearmament tax on salaries [Ref. 29].

Economic costs have included a reduction in potential civilian employment and GNP available for non-military uses because resources allocated to military ends largely go for development purposes.

The United States has provided a great deal of military support and economic assistance to Korea since the Marshall Plan. The reasons why the Republic of Korea has received great defense-related foreign exchange earnings can be explained in terms of its strategic location between China and Japan, the heritage of the American Military Government era, the Korean War legacy, and Vietnam War requirements. However, the apparent danger of attack from the North has undoubtedly shared responsibility for securing the economic as well as the military assistance provided by the United States. For this reason, Korea's costs to maintain an oversized military establishment should be reduced by assistance received to support it and by any possible economic benefits of military activities.

Confrontation with the North has not only had political consequences and a direct impact on resource allocation by diverting more resources to military activities than would otherwise have been the case, but it has also been used to justify the sacrifices associated with accelerated growth. Growth has an additional dimension when it is thought to contribute to national security. It can be argued that superior economic performance is needed for protection against incursions from the North, and also strong defense power is needed for protection against invasion from the North.

Besides the direct relationship between economic growth and national defense to protect each other, some positive fiscal impacts have resulted from the nation's economic life from the military establishment. Korea has needed a large number of managerial and technically oriented personnel to meet rapidly expanding productivity. Officers and men discharged from the military service entered both the private and the public sectors and their managerial and technical skills, obtained by training in the military, contributed to building up today's Korean economy. Also, under civic action programs promoted by the military, men and equipment were provided to help in building and repairing roads, dams, schools, and hospitals in the private sector as well as in local communities. One important factor was the general policy of using the armed forces and military facilities for disaster assistance and in large public projects such as flood control. These activities had an important and usually beneficial effect on the nation's economic life.

As the structure of the economy changes, many more instances of cooperation among the different sectors of economic society will be required. Korean military authority has to consider the length of time necessary to meet economic growth and structural change. The defense burden, which was 10.6% in 1961, had fallen to 6.2% by 1976, with an annual average for 1961-1976 of 6.9%. The reason for the downward trend of the Korean defense burden was the country's relatively high growth rate of GNP [Ref. 30].

That is, defense expenditures were relatively less because there was no significant investment to buy or produce equipment. But this fact should be changed in the not so distant fugure. Most of the equipment being used now has been provided by the U.S. in terms of Grant Aid by the Military Assistance Program (MAP). When this equipment becomes obsolete, replacements should be procured by Korea's own budget. It is clear that the defense budget must be increased by tremendous amounts to buy such substitutes either in foreign military sales or in-country products of defense industries.

Another reason for the anticipated increase in the defense budget is that research and development expenditures will be greater in the future. Recently newspapers reported that Korea has developed a medium-range guided missile and a small submarine. Still large amounts of effort and funding will be needed to make technological advances as Korea's technological level of mass production and performance is not advanced enough to make such sophisticated modern weapons at this stage.

Considering that North Korea has still not developed highly advanced arms while spending 30% of its GNP in the defense sector every year, it is doubtful that Korea can allot such a proportion of its GNP to the defense sector and also catch up with the advanced nations in arms development [Ref. 31].

D. ISSUES OF SELF-RELIANCE IN DEFENSE

Two kinds of problems which are foreseeable for defense-reliance arise at this stage. One of the problems is to secure enough funds to achieve self-reliance. The other problem is how to spend these funds to maximize effectiveness.

Allocation and/or appropriation of national resources to the defense sector is strictly a matter of national priority and strategy. So it can be affected by internal and external trends, the political situation, economic status, and many other socio-political and socio-economic factors. It is certain that Korea cannot expect the kind of outside support it has had during the past several decades. Consequently, the defense burden must be imposed on the people to the greatest possible extent.

Maximizing the effectiveness of the allocated budget is absolutely a matter of management and operation. However, all of the management effort must be consentrated on utilizing the given defense budget effectively. Self-supply and self-sufficiency of required qualified arms and materials must be achieved so as to minimize the people's defense burden and finally to restrain the enemy.

The trend of the U.S. military assistance to Korea is toward technological support. The common communique of the U.S.-R.O.K. defense conference, 1979, said the U.S. will positively support Korean defense industries except in producing nuclear bombs. Korean defense industries now are producing small arms, cannons, high-speed patrol boats,

armored personnel carriers, tanks, helicopters, and are scheduled to produce F-5E fighters by 1981 [Ref. 32].

Such production is initiated by direct or indirect support of the U.S. in terms of transferring know-how, affording license, and co-production.

As the structure and status of the economy changes, the forms and policies of military assistance to Korea from the outside, particularly from the U.S., changes.

The important thing to be considered is that the attitude toward receiving assistance should be changed.

The 12th U.S.-R.O.K. Security Conference held in Seoul in October 1979 suggested that there were certain changes of attitude concerning Korea on both sides. The conference was conducted at a higher level than that of previous conferences which usually discussed what was given and taken mutually. The results of this conference are: both sides affirmed once again that Korea is the principal axis for peace and security in Northeast Asia; the U.S. reconfirmed its benefits from Korea which has grown as a companion; and Korea gained actual products for consolidating its base of self-reliance in defense [Ref. 33].

Self-reliance in defense is very difficult to define. It is more complicated in a situation of collective security. In a certain sense, self-reliance could be said to be complete when a nation maintains its own security with its own resources. But the criteria might be changed according to the

situation because there are too many variables in the real world.

The amount of resources needed at a given time may differ according to the threat pressed at that time. And resources are always scarce. More important in self-reliance is the nation's will and its ability to mobilize required resources from others.

The U.S. has changed its policy to treat Korea as a most favored nation by moving from Group "A" to Group "B" the properties for foreign military sales. It has agreed to assemble and produce F-5E fighters in Korea and promised to raise the level of technology for supporting the Korean defense industry. This can be understood in the sense of mobilizing other resources. This means the attitude of Korea as a recipient has changed. The change has been brought about by the changed setting of economic growth, current trends, and military strength. Changing attitudes created the will and value to achieve self-reliance.

Koreans began to feel more strongly the necessity of self-reliance in 1969 with the announcement and implementations of the Nixon Doctrine. Korea assessed the probable present and future impacts of the doctrine, being mindful of the restive mood of the U.S. Congress and people at that time. Also Korea examined the traditional model which was based on the concept of the Cold War. Korea foresaw that its relationship with the U.S. would rapidly change and its client status would soon end. Consequently, Koreans came to the conclusion

that the only way they could assure their national survival under such circumstances was to quickly become as self-sufficient as possible in all vital areas affecting their national existence. They deemed it desirable to achieve the capability to travel an independent course without being critically dependent upon the U.S. for any form of assistance.

Jack G. Callaway discussed the conditions of self-sufficiency as follows [Ref. 34]:

> Economic -- There should be continuous maturation of the economy that might range between a six and nine percent GNP growing rate; continuation of high drive export to GNP ratios; continued expansion of markets; increased marketability and continued diversification of products; continued growth in high technology manufacturing; continued diversification and increase of foreign investors; continued diversification of reliance on energy sources.
>
> Political -- There should continue to be domestic political stability. This will require that there be a most precise assessment of the expectations of the population and their ability to tolerate frustration in achieving the more important of these desires. It will also require careful planning in order to achieve balance between fulfilling the citizens' expectations and continuing to call for self-sacrifice in the name of national security and continued economic growth. It should be recognized by friends of the Republic that some forms of criticism of the nature of the ROK Government can be counterproductive and prejudicial to the national interest of both countries. It should also be recognized that American-style democracy is not always exportable.
>
> Military -- Modernization and improvement of the ROK armed forces should continue until the situation has been reached in which the North does not have a quantitative or qualitative advantage over the South that might be decisive in the event of war. The deterrent value of U.S. forces as well as their deployment on the Peninsula should be matched to the perception of our allies in the area, the ROK and Japan, and also to those of the PRC and USSR but most espcially to those of the DPRK.

The President of Korea and other officials stated when and to what degree military self-sufficiency would be achieved. Their statement said that the modernization program for Korea's armed forces will be complete in 1980 and there will no longer be any need for U.S. military presence or military assistance to repel an attack launched by the North Koreans which is not supported by either China or the Soviet Union. Many Koreans and Americans believe that when this condition has been achieved, a high degree of self-sufficiency will also have been achieved.

Colonel Callaway sees a fundamental problem in implementing this self-sufficiency plan. It is how to synchronize the withdrawal of the U.S. military presence so that it does not destabilize the current equilibrium, while still allowing the Republic of Korea to move toward self-sufficiency as rapidly as possible and free from unnecessary impediments to solid progress [Ref. 35].

When taken one step further, in relation to changing current trends, arms competition, and the production capability of the defense industry, it seems not such a simple problem.

There is no way to know when and how the world situation will change. The model of the Cold War* has broken. In the aspect of arms competition with North Korea, the view is

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*The model of the Cold War is that the U.S. in on South Korea's side and the Union of Soviet Socialist Republics and the People's Republic of China are on North Korea's side.

not optimistic. For example, Russia was far behind America in military technology. But, once Russia committed tremendous effort to the military sector, the quality and quantity of Russian armed forces threatened America. Because a communist nation can allocate its resources to one particular sector, it is very dangerous to try to compete in one area with a communist nation.

Lack of production capacity in defense industries can be thought of in two aspects. The first is lack of sources and lack of capability of the selected source. The second is surplus of capacity of the selected source.

In the case of surplus, it is caused by too much specialization for a particular military item. Lack of sources, or capability of the selected source, is due to the short history of the defense industry.

Korea must not be satisfied with a level of self-sufficiency in equilibrium with North Korea's present strength. Korea must provide for the changeable world situation in the future.

For these reasons, Korea has to broaden its industrial base for defense, providing many entities with the opportunity to participate in the defense industry, supporting capacity surplus entities to look for foreign markets, supplying advanced technology to general industries as well as the defense industry.

In short, a principal issue for Korean military self-sufficiency or self-reliance in defense is to distribute

opportunity and technology fairly to all entities which will participate in defense-related programs, and to transfer the technology outside the military sector so that the Korean economy will be developed in balance.

III. MANAGING TECHNOLOGY TRANSFER

A. IMPORTANCE OF TECHNOLOGY AND ITS TRANSFER

Economists perceive technology as society's pool of knowledge regarding the industrial and agricultural arts. They need advanced technology or technological change to get the maximum output rate that can be achieved from a given amount of input. Therefore, they expect technology change to result in a change in the production function so as to increase economic welfare through the alteration of production functions due to technological change [Ref. 36].

Scientists understand technology is producing some physical changes in the world. Therefore, they see a fundamental and inherent incompatibility between input and output in technology [Ref. 37].

Strategists emphasize technology to improve the quality of weapons. They need new and better technology to make better weapons [Ref. 38].

The importance of technology and its transfer is perceived differently according to what one wants to get from technology. Therefore, there is not one universally accepted definition of technology transfer. But most people who are familiar with the general meaning would agree that technology transfer is inherently good. When it occurs there is at least some small economic, social or other benefit [Ref. 39].

For the purpose of this thesis, the importance of technology is discussed in the military aspect; therefore, technology

transfer is considered to be the process which "encompasses the collection, documentation, and dissemination of scientific and technical information, including data on the performance and cost of using the technology; the transformation of research and technology into processes, products, and services that can be applied to public or private needs; and the secondary application of research or technology developed for a particular mission that fills the needs in another environment" [Ref. 40].

The importance of military technology is well described in the FY 1980 Department of Defense Budget requests for research, development and acquisition activities. Dr. Harold Brown, Secretary of Defense, emphasized that this request reflected the continuing concern of the U.S. over the significant growth in both quality and quantity of Soviet weapons and technology and established the following three major objectives:

- Better justification of programs on the basis of mission needs to reduce waste and duplication;
- Strengthened technology base;
- Greater cooperation with allies.

He also stated that through exploration of innovative technology and through improved management of science and technology resources, it is possible to accelerate the pace of technology so as to expand available technology options. This will allow greater selectivity and lower costs in the more expensive acquisition portion of the total research, development and acquisition process. He supported increasing

funds to prevent technological surprise; combining efforts of the federal, industrial, and university communities to increase productivity in the production process, a creative, independent industrial research and development program, and a high level of innovation within all of these communities; appropriate management of export controls to prevent a military advantage to political adversaries, and an opportunity for industry to acquire additional resources which can further be allocated to industrial research and development programs for the improvement of the national technological position; cooperative research and development projects with allies to provide for a stronger and more effective defense by increasing real growth in the military science and technology programs and improving the exchange of technological information between countries [Ref. 41].

The size of Research, Development, Test and Evaluation (RDT&E) funding was 28.85% of the total budget in 1979 and the ratio to procurement funding was 1 to 2.46 (40.65%). The specific gravity of the science and technology program in RDT&E funding was 19.88% in 1979. The requested budget for RDT&E funding in 1980 was increased about 10% over that of 1979, and composition of the funds was about the same as the previous year.

This budget structure shows how much the U.S. military concentrates its efforts on science and technology programs as well as on overall research and development activities.

PROCUREMENT FUNDING

U.S. DEPARTMENT OF DEFENSE

($ Millions)

	FY 1979	FY 1980
Strategic Forces	2, 995	4,914
General Purpose Forces	22,140	23,624
Intelligence and Communications	3,016	3,381
Airlift and Sealift	389	402
Guard and Reserve Forces	1,448	1,275
Central Supply and Maintenance	927	1,013
Training, Medical, and Other Personnel Activities	452	503
Administration and Associated Activities	48	63
Support Other Nations	85	250
Total	31,500	35,425

Source: Command Policy, DoD, Vol. 2, No. 8, August 1979

TABLE VIII

RDT&E FUNDING

U.S. DEPARTMENT OF DEFENSE

($ million)

	FY 1979	FY 1980
Strategic Warfare (1)	2,383	2,408
Tactical Warfare (2)	5,310	5,251
Defense-Wide C3I	672	910
Other Defense-Wide Mission Support of Management	1,869	2,089
Science & Technology Program	2,540	2,950
	12,774	13,606

(1) Includes Strategic C3I Funding

(2) Includes Tactical C3I Funding

Source: Command Policy, DoD, Vol. 2, No. 8, August 1979.

TABLE IX

Considering that the U.S. leads in technology around the world and it needs this amount of funds just to reduce the possibility of technological surprise, it is easily recognized that Korea, which is backward in technology and located at a strategic point where the powerful nations easily collide with each other, must concentrate its efforts much more on technological innovation.

It is true that the Korean government strongly desires military self-reliance and pushes governmental research agencies and private enterprise to develop a defense industry rapidly. Even more, Korean government officials hope to finance the expanding defense bill by exporting Korean-made arms. Many analysts predict that if Korea develops its defense industry as rapidly and efficiently as its other industries, it will soon be offering competition to the U.S. and European arms manufacturers [Ref. 42].

Therefore, the Korean military needs more advanced technology and much more funding for research and development. These needs create complex management problems. Major objectives for the formulation of the U.S. DoD Research, Development and Acquisition (RD&A) suggest a way of solving the problems. Advanced technology will be developed from the basis of a strengthened technology base. The technology base will be formulated by research and by combined efforts of the federal, industrial, and university communities. Cooperation with allies can also be a great help in improving technology.

Reduction of waste and duplication would contribute to saving funds while accelerating technological innovation.

It is obvious that all those matters are associated with transfer of technology. It is time that the Korean military research and development establishment open the door, which is closed for reasons of military security, to other public, industrial, and university communities. This open-door policy will contribute to the growth of research and development throughout the country and will promote technology transfer. The importance of this open-door policy and technology transfer can be recognized by looking at the Areas of Federal Research and Development (see Appendix A) and Federal Outlays for Research and Development (see Appendix B) of the United States.

This policy will accelerate technological change which will cause multiplier effects on economic growth, with first-order effects being physical changes in terms of new materials, designs, and production methods. These modifications induce social consequences that in turn feed back and alter the preferences for further innovation through the kinds of new research that are performed [Ref. 43].

American industries gained 17% of all 1971 sales by selling new products, with the aerospace industry leading all others by obtaining 49% of its 1971 sales from new items. Also some communities in Florida and Alabama witnessed more than 100% growth between 1960 and 1965 in per capita income, school construction, residential building permits, and retail sales.

PERCENT OF NEW PRODUCT SALES TO TOTAL SALES IN THE UNITED STATES IN 1971

Industry	Percent of 1971 Sales	Billions of 1967 dollars
Iron and Steel	7%	$ 2.60
Nonferrous Metals	14	2.43
Machinery	22	12.93
Electrical Machinery	24	13.68
Autos, Trucks and Parts	24	12.81
Aerospace	49	18.52
Other Transportation Equipment	20	1.40
Fabricated Metals and Instruments	24	11.82
Stone, Clay and Glass	16	2.54
Other Durables	22	9.00
TOTAL DURABLES	23	87.73
Chemicals	16	8.98
Paper and Pump	8	2.31
Rubber	9	1.52
Petroleum and Coal Products	8	2.03
Food and Beverages	8	9.28
Textiles	20	4.98
Other Nondurables	6	4.15
TOTAL NONDURABLES	10	33.32
ALL MANUFACTURING	17	121.05

Source: McGraw-Hill, Survey of Business Plans for New Products

TABLE X

REGIONAL IMPACT OF NASA PROGRAMS

	Huntsville Alabama		Brevard County Florida	
	1960	1965	1960	1965
Population	72,000	144,000	111,000	225,000
School Enrollment	15,300	32,200	20,200	48,200
Public School Classrooms	538	1,010	651	1,519
Residential Building Permits	1,436	5,066	2,614	6,933
Personal Income per Capita	1,537	2,054	2,319	3,435
Retail Sales (Thousands)	11,300	207,800	125,400	291,300

Source: M. A. Holman and R. M. Konkel, Manned Space Flight and Employment, Monthly Labor Review, March 1968.

TABLE XI

The U.S. Government expects universities and colleges to perform research in all the academic areas. Though the U. S. Government provides some support, basic research is closely associated with institutions granting Ph.D. degrees. However, the U.S. Government awards large amounts of R&D funding for academic research to universities and colleges [Ref. 44].

Also, the U.S. hopes to reduce waste by emphasizing cooperation with its NATO allies. Thomas A. Callaghan, Jr. reports NATO's failure as follows [Ref. 45]:

"The past quarter century has witness an incalculable waste of American and European defense resources-manpower, money, materials and structures because the North Atlantic Alliance has failed to achieve:

- Common military requirements for weapons and equipment
  * Thru common tactical doctrine
- Complementary research and development projects
  * Thru rationalization of development tasks
  * Thru specialization in development areas
- A diversity of weapon system options and hardward
  * Thru a U.S./European technology base
  * Thru savings in system acquisition and support practices
- Larger weapons inventories at lower unit cost
  * Thru rationalization of production sources
  * Thru production runs on the combined European-American scale

- Mutually supporting general purpose forces
    * Thru standardization of weapons and equipment
    * Thru common spares and maintenance logistics
- A balanced, collective, conventional force deterrent
    * Thru military, technological and industrial interdependence
    * Thru marshalling available economic means to achieve desired military ends
- Equitable financial burden-sharing in all defense areas
    * Thru economic and technological benefit-sharing
- Jobs and markets for under-employed defense industries
    * Thru non-duplicative projects on an Atlantic development and production scale
    * Thru a North Atlantic common defense market."

Callaghan further asserts that 100% of European R&D expenditures, 10% of American procurement expenditures plus 25% of European procurement, and 10% of direct American annual NATO costs plus 15% of European general-purpose forces expenditures were annual Allied waste.

For reduction of Allied defense budgets, he continued, NATO industrial rationalization and standardization should be undertaken and this action would:

- Increase the quality, quantity and diversity of Allied general purpose forces,
- Enhance the military effectiveness of the Allied conventional deterrent,
- Create new defense industry jobs on each side of the Atlantic and ultimately,
- Permit the gradual reduction of defense expenditures, first in the United States and then later in Europe.

The realities discussed so far can be perceived as the benefits or importance of technology transfer. But technological information is not easily controlled.

B. THE NATURE OF TECHNOLOGY TRANSFER

Technology is distinguished from science not only by the kinds of people who are attracted to them but also by the nature of the activities themselves. In science, all of the work up to any point can be found permanently recorded in the literature which serves as a repository for all scientific knowledge.

In contrast, information is transferred in technology primarily through personal contact. Publication occupies a position of less importance than it does in science where it serves to document the end product and establish priority. Unlike scientists, the vast majority of technologists are employed by organizations with a well-defined mission (profit, national defense, space exploration, population abatement, and so forth). This organizational identification works in two ways to exclude the technologist from informal communication channels outside his organization. First, he is inhibited by the requirements that he work only on problems that are of interest to his employer and, second, he must refrain from early disclosure of the results of his research in order to maintain his employer's advantage over competitors. A good proportion of the truly important information generated in an industrial laboratory cannot be published in the open

literature because it is considered proprietary and must be protected [Ref. 46].

The problem of supplying information to the scientist thus becomes one of systematically collecting and organizing scientific outputs and making them accessible to other scientists to employ in their work. In technology, on the other hand, there is a fundamental and inherent incompatibility between input and output. Outputs can hardly be utilized as inputs to the next stage because outputs are in a form basically different from inputs. Sometimes technologists analyze a competitor's product or weapon systems in order to gain information. This is a difficult and uncertain process, however. It would be much simpler if the information were directly available in written form [Ref. 47].

There are many variables in the area of technology transfer. Some of them which can affect the diffusion of technology are: characteristics related to the innovation; characteristics of the adaptor; sources of information and information channels; a number of environmental or contextual variables. In a general thrust at the problem, incorporating many of these variables, Harvey Brooks has suggested two different kinds of technology transfer which he calls vertical and horizontal [Ref. 48]. In vertical transfer, there is a direct movement from one phase or level to another; the general is transformed to the specific; basic scientific knowledge becomes technology; technology is embodied into a hardware system.

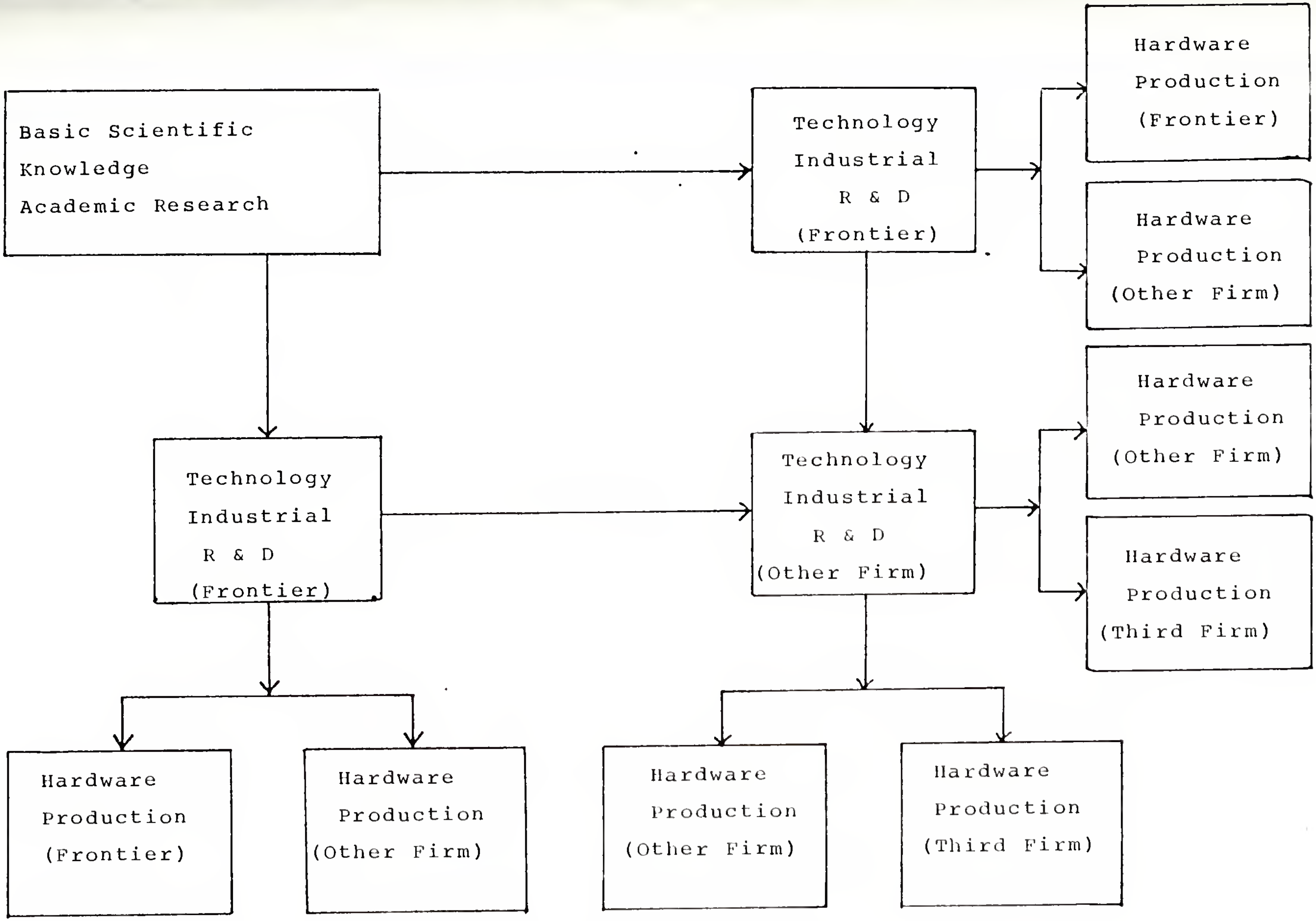

Figure 5 : Vertical and Horizontal Flow of S&T Information

Hoeizontal transfer refers to the adaptation of technology from one use to another possibly unrelated application: A firm borrows technology from one field and introduces it into its own area; a laboratory device is modified to be useful in industrial practice; technical assistance is utilized in an underdeveloped country; military/space technology is diffused into the general commercial market. According to the characteristics of innovation, both horizontal and vertical transfer will occur simultaneously or immediately after one another [Ref. 49].

The pattern of technology transfer as described above indicates the need for a certain degree of organized effort. Usually research and development laboratories are within the technology industries. At lower echelons of these facilities, there are also functional or project organizations which have specific responsibilities for product or process development or cost savings. Figure 4 is a diagram of a typical pattern of vertical and horizontal transfer of technology.

Within the pattern of technology transfer, there may be many barriers as mentioned previously. Since technology transfer has been redefined as "a purposive, conscious effort to move technical devices, materials, methods, and/or information from the point of discovery or development to new users, the barriers existing between source and user must be removed" [Ref. 50].

Availability of information is not sufficient for its transfer or use. There must be both "technology push" and

"requirement pull" to effect technology transfer [Ref. 51]. Then "technology push" and "requirement pull" should be matched. If there is no commonality between the two sides, technology can hardly be transferred. Therefore, considerable focused effort to actively transfer the particular technology should occur so as to expedite the transformation of knowledge into meaningful innovation [Ref. 52].

Conscious and well contrived types of human interactions can expedite a transfer mechanism. Professor J. W. Creighton and others first developed a technology transfer process model in 1972 and explained the concept of a transfer mechanism as follows [Ref. 53]:

> "One method for putting the dynamics of technology transfer into a usable perspective is to begin discussing a 'transfer mechanism.' In simplified terms, the transfer process must include a set of activities designed to effectively link or couple the source of the needed knowledge with its eventual user."

A simplified view of the transfer mechanism developed by Professor Creighton and others is shown in Figure 5. This transfer mechanism represents the interaction of people and need not be independent but may be incorporated into either the supplier or user environment.

This simplified model has been developed further, emphasizing the importance of both the potential user's standpoint and the literature support in this field. Whether it is the vertical flow of technology, i.e., from a laboratory to a given application, in a given discipline, or the horizontal transfer of technology, as from one industry or activity to

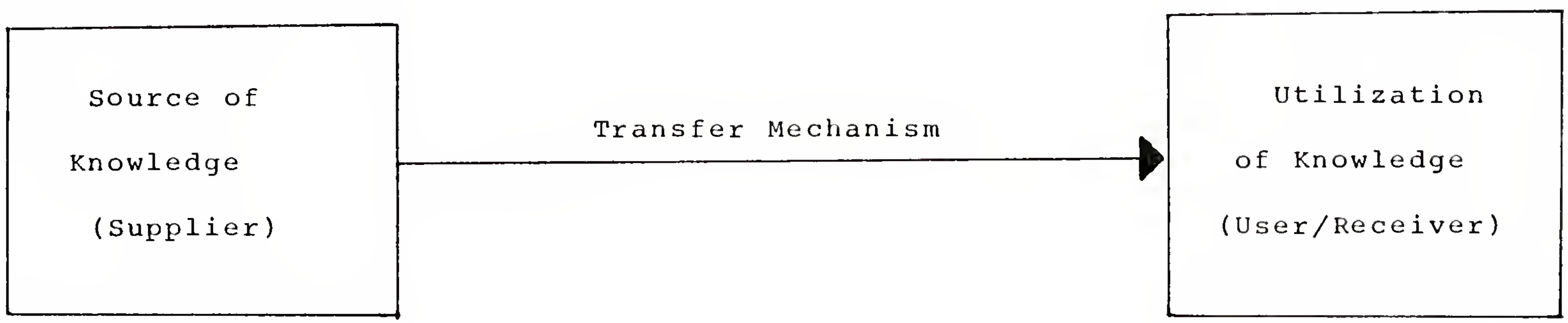

Figure 6 : A Simplified View of the Transfer Mechanism

another, the source signal must be transferred through time and space which is filled in by certain media. The media or factors which organize the transfer mechanism have not been measured as to their effect on the transfer mechanism in a given organizational situation. These factors are divided into two parts: formal factors and informal factors. Formal factors are system oriented and can be easily handled and operated directly. Informal factors are highly behavioral and sociological and are quite difficult to handle.

Recently there has been a trend that recognizes technology transfer as a "people" thing and takes a serious view of informal factors [Ref. 54]. One report to Congress explains the importance of informal factors quite well:

> "Ther mere availability of information does not cause its transfer or use. Printed materials alone, even expertly prepared, cannot stimulate interpersonal relations, define a problem, answer related questions, involve consulting authorities, provide follow-through on problems or relate to other agencies" [Ref. 55].

But there is a necessary step to understanding the technology transfer process. The formal factors should be perceived as the first and basic step to transfer technology. These are procedures for dissemination of storage, indexing and retrieval of knowledge.

John W. Murdock distinguished technology transfer from information transfer by its capacity to bring the industrial processes into action [Ref. 56]. He divided it into three progressive levels:

(1) Basic Information Storage and Retrieval Systems (Fig. 7),

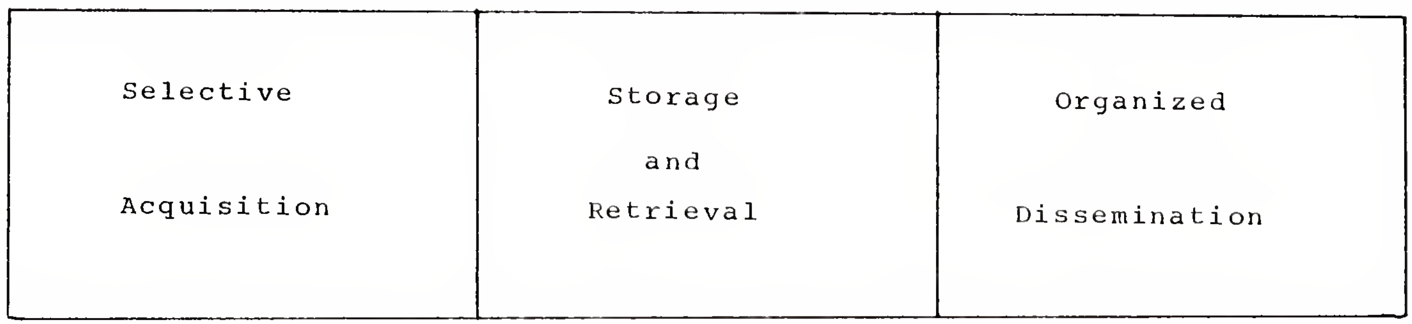

Figure 7 : Basic Information Storage and Retrieval System

(2) Information Analysis System (Fig. 8),

(3) Technology Transfer System (Fig. 9).

Figure 9 shows the primary function of scientific information analysis centers.

The informal factors are perceived as the second dimension. These are more complicated to manage because their science base is primarily behavioral rather than physical [Ref. 57]. For further understanding, the Linker Model diagram is exhibited and each of its factors is briefly discussed.

DOCUMENTATION(DOCU) is the format, specifications, and presentation of the technology or information being transferred. It can take a variety of forms, but it must be understandable by the users.

DISTRIBUTION(DIST) is the physical channels used to distribute the information. It is accomplished by interpersonal communication, computer assistance, a journal, or by another vehicle. It is the only factor which will determine the success of a technology transfer effort.

ORGANIZATION(ORGA) is the impact that the formal organization of the potential technology user has upon a transfer effort. It is a very important factor in which characteristics of technology transfer can be determined according to the power structure, the nature of the business, the management style, resources, attitudes, bureaucratic tendencies, rules, and norms.

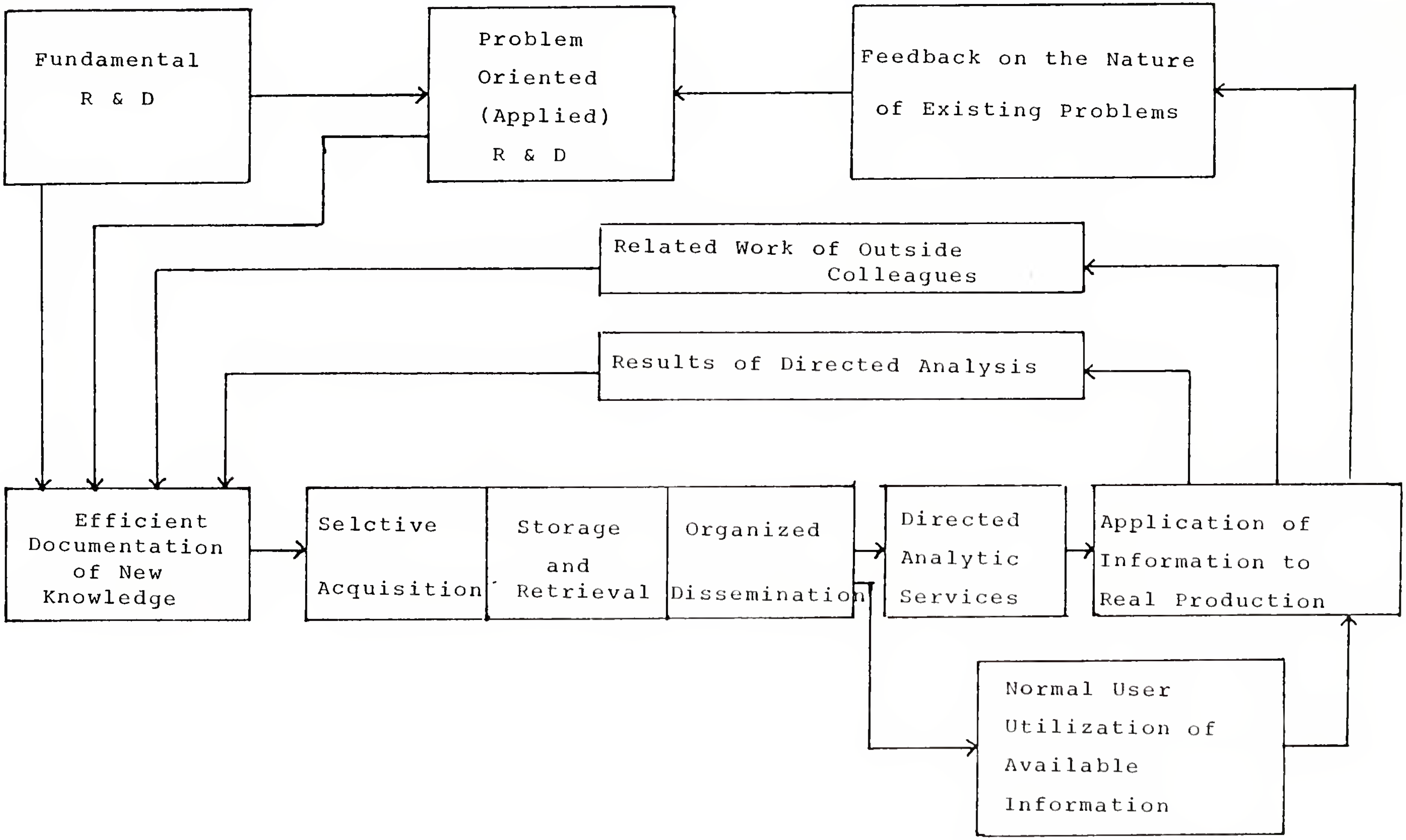

Figure 8 : The Information Analysis System

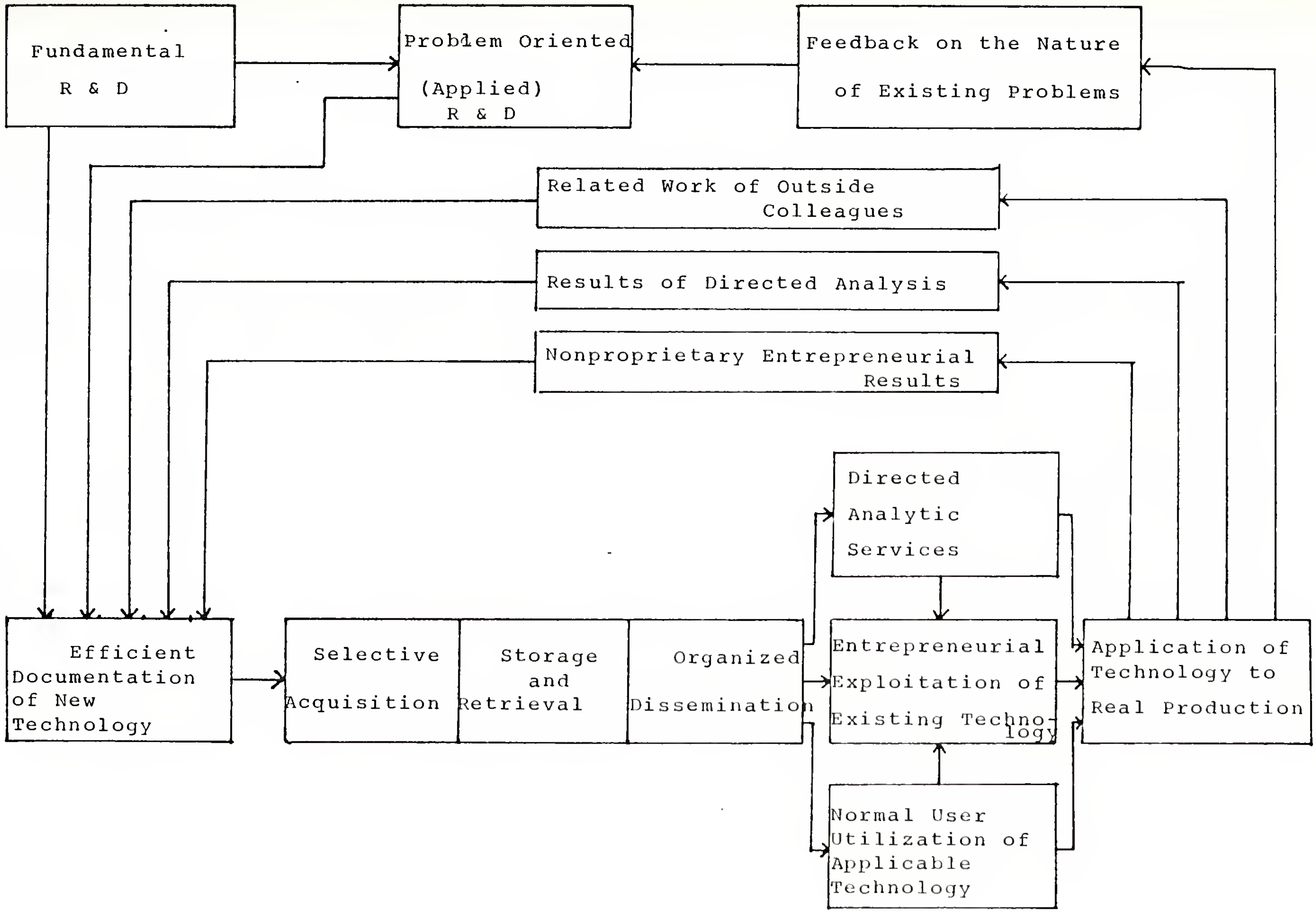

Figure 9 : The Technology Transfer System

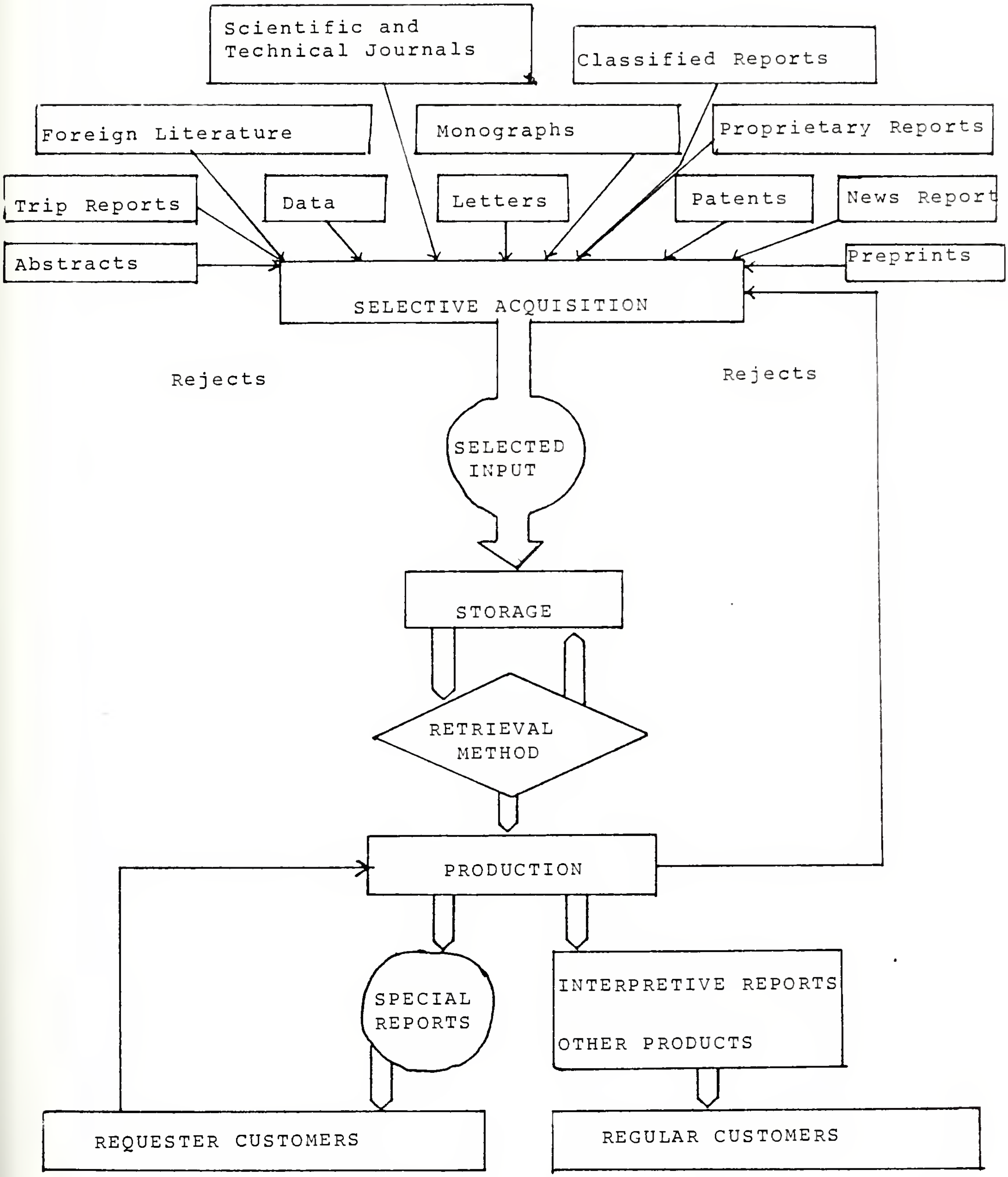

Figure 10 : The Primary Function of Scientific Information Analysis Centers

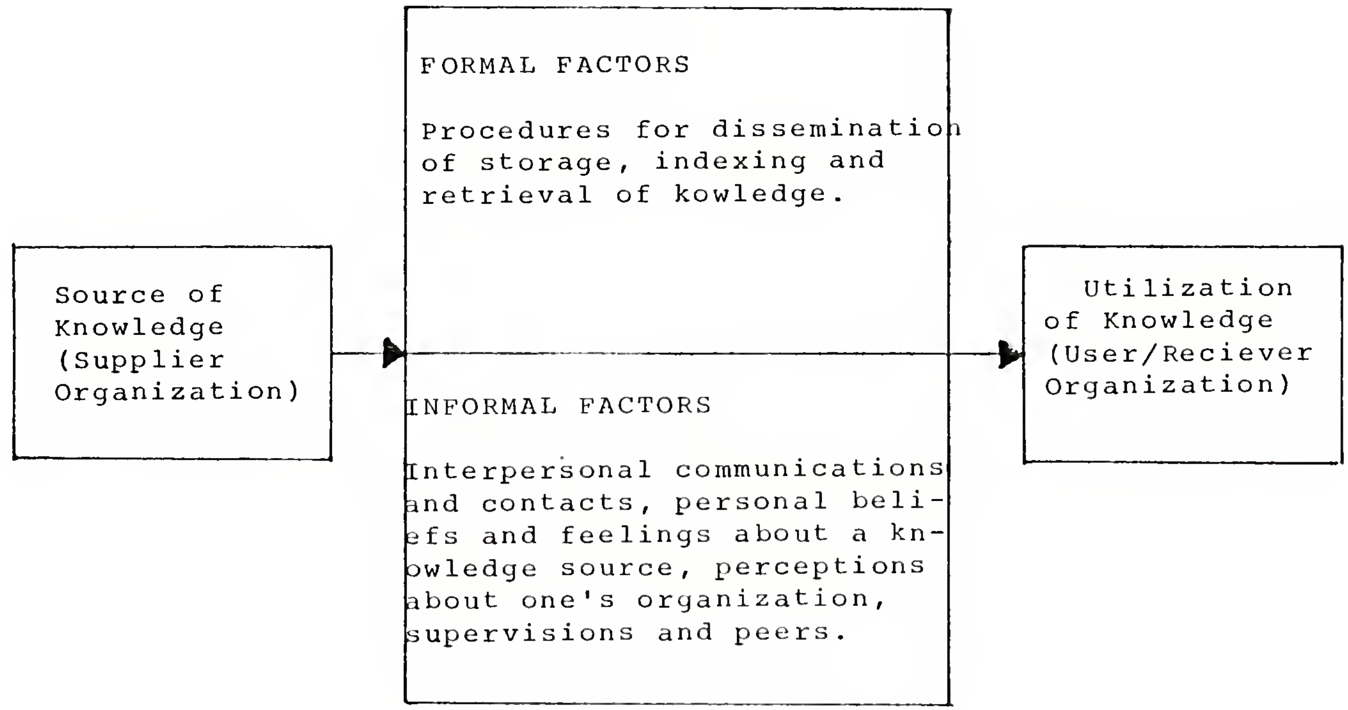

Figure 11 : A Simplified Model of Technology Transfer

PROJECT SELECTION(PROJ) is the selection process for research and development undertaken by the source and receiver's contributions to that process. The effectiveness of the utilization of research differs with the entities who initiate the project.

CAPACITY(CAPA) is the ability and capability of the potential user to utilize new and/or innovative ideas. It would be different from individual to individual whose levels of venturesomeness, wealth, power, education, experience, age, self-confidence, etc., differ. The capacity should integrate all the key players' and groups' capacities.

LINKER(LINK) is the individual or group of individuals who link the source and the application. Linker fills the roles of leader (gatekeeper or opinion leader), early adopter of an innovation (innovator), and early knower of an innovation.

CREDIBILITY(CRED) is the receiver's assessment of the reliability of the information before him. Incredible sources should be rejected by the potential user.

REWARD(REWA) is a compensation which is given to a new technology adopter as a consequence of applying technology. If a man is to be penalized rather than rewarded, he will most certainly be disinclined to import a new technology idea.

WILLINGNESS(WILL) is the individual's ability and/or desire to accept change in the organization of which he is a member. Willingness will create interest or motivation.

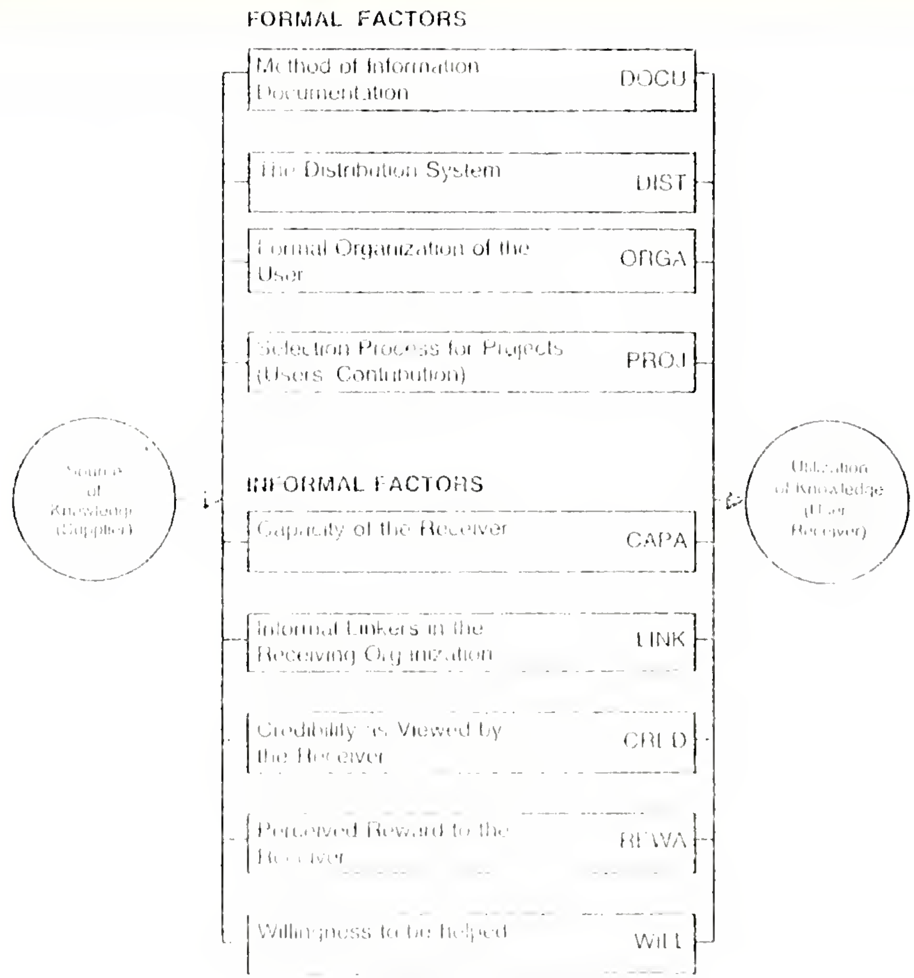

Figure 12: An Expansion Model of Technology Transfer

Without motivation, a better method, process, or concept will not be utilized [Ref. 58].

These fairly complex factors are, as mentioned already, not for just the flow of information but for the conscious transfer of technology. To guide technology transfer in the desired direction is important to accelerate the rate of technology innovation. None of the formal and informal factors in the technology transfer process can be eliminated in a technologically backward nation.

C. THE ROLE OF THE KOREAN MINISTRY OF DEFENSE IN TECHNOLOGY TRANSFER

The Korean Defense Authority has many responsibilities in relation to self-sufficiency. These responsibilities can be roughly divided into internal and external ones. Internally, the Korean military should be in a high state of combat readiness to maintain the country's safety. It is an inevitable duty, the primary mission of the military. The secondary responsibility of the Korean military is to participate in civic actions in order to support local communities. The reason for this duty is that almost one fifth of the Korean labor force is in the military. The third responsibility is to transfer appropriate technology to the civil sector. The Korean military has had many opportunities to contact advanced technology by importing new weapons and equipment, by combined operations with allies, especially with the U.S., and by training many personnel abroad. Furthermore, the military is increasing research and development activities

as a national priority. This third responsibility is derived from the necessity to repay the taxpayers.

The external responsibilities are set up, first, to secure peace for Korea by maintaining the Korean military at the proper level to guarantee Northeast Asia's stability; second, to contribute to allies' efforts for collective security by reducing foreign assistance; third, to develop appropriate technology to meet Korean needs so as to relieve allies of the burden of research and development for technologically backward nations.

Internally and externally, the Korean Military Authority has responsibility for technological innovation and its transfer. To fulfill this responsibility, the Korean Ministry of National Defense must undertake an important role. That is the role of a catalyst.

As mentioned earlier, the Korean military is in a favorable position to import advanced technology under any conditions of payment. This situation will last as long as the allies, particularly the U.S., want stability in Northeast Asia. The Korean military is also in a situation to carry out this role internally. That is because a trend to develop appropriate or intermediate technology jointly with advanced nations exists in the Korean research and development field, and industries which rush to change their structure need new technology and jobs.

The Korean military can affect almost all Korean industries in regard to small domestic markets and poor

progress of research and development activities among the industries.

From this point of view, the Korean Military Authority, Ministry of National Defense, can act the role of a catalyst in the technology transfer process. A catalyst can act more powerfully than a simple linker. A linker simply connects or couples one presence to another. A catalyst not only couples two subjects together but also changes the characteristics of those two subjects. In other words, the Korean Military Authority should stand at the middle of a vertical transfer of technology rather than of a horizontal flow. Reality requires a three-dimensional role for the Korean military. Receiving, innovating, and transferring the appropriate technology are equally important. The three should be simultaneous and parallel.

In this sense, the Korean Military Authority is a receiver and supplier of the technology at the same time. As a receiver, the Korean Military Authority seems to have little problem in the informal factors. They are so eager to import or receive advanced technology that Willingness, Reward, and Credibility factors of the Expansion Model of Technology Transfer are sure to be solved. Informal linkers will also come into being because the Korean military has used foreign arms, mostly U.S. arms, for a long time. There is not much of a problem with Capacity except in highly precise equipment and nuclear weapon production.

There are major problems in formal factors. The fact is that the Korean Military Authority is not functioning at all in the Selection Process for Projects. There are no organized selective acquisition activities, no storage and retrieval facilities nor offices, and also no organized dissemination function. The Formal Organization factor presents much to be discussed, however. Jack G. Callaway stated that the Korean military is a highly professional, highly disciplined and motivated force [Ref. 59]. The general feeling of the author about this factor is that there is a lack of delegation of authority and most decisions are made by authoritarian management.

Considering the supplier side, there is a basic problem to be solved. There are no Documentation Activities, no Distribution System at all. As stated previously the Korean military is ignorant of technology transfer discipline.

Observing industrial firms from the position of information supplier, the Korean Military Authority is confronted with two kinds of problems. The first is that a firm has Capacity but has no Willingness. The second is vice versa. The first case exists among big enterprises which can exploit the foreign market. They do not want to shift existing production lines or facilities to new production lines or facilities for a small domestic market. For the same reason, they do not want to invest in a new production facility. Because the Korean defense industrial base is not broad,

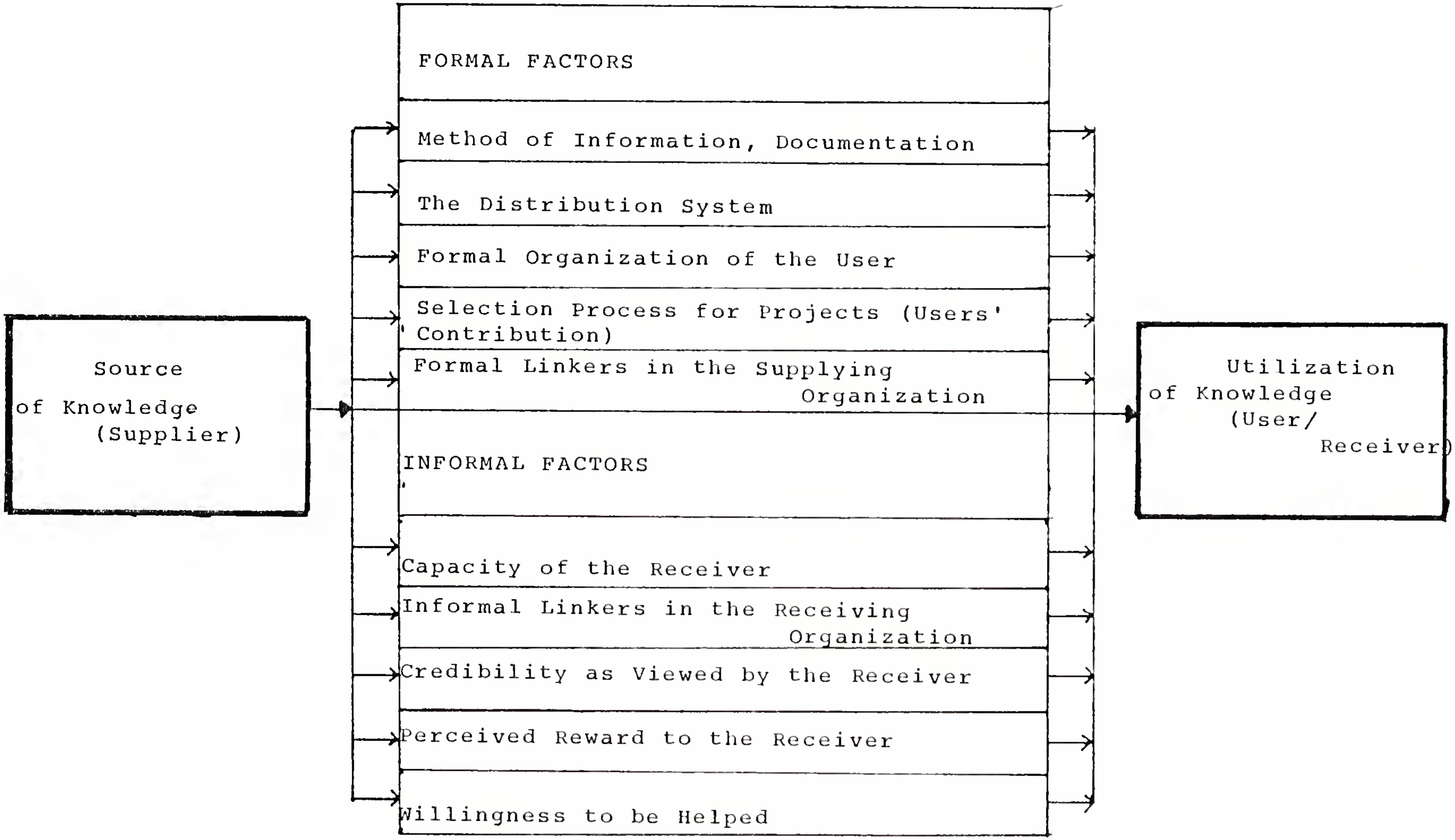

Figure 13 : A Modified Linker Model

the firms are receiving technology information under the condition which requires them to make military articles. The general spirit of the Korean enterprises for making profits explains this situation fairly well; however, a typical case is the trend of the Sang Sung Group, one of the biggest enterprises in Korea [Ref. 60].

The second case is happening among small businesses. They have no capacity in terms of technology and capital. But they seriously want jobs. The Korean Military Authority has to analyze the status of firms in order to find adequate users. Thus it plays a linker role on the supplier side.

D. STRUCTURING THE ORGANIZATION TO MANAGE TECHNOLOGY TRANSFER

Now the Korean Military Authority has to do something to solve the problem mentioned above. It is considered urgent as long as military self-sufficiency has top priority as a national goal.

The Linker Model developed in the U.S. by Professor Creighton and others could be modified to meet Korean needs. By adding formal linkers in the supplying organization among the formal factors, the Korean Military Authority can accelerate transfer of technology and control its process.

Figure 13 shows the modified model of technology transfer.

There must be an agency which can suggest military technological information to be reflected as the national stretegy or policy. There are agencies which are associated

with the defense industry in the Korean military establishment. One of them is the Agency of Defense Development (ADD), a laboratory for research and development in all areas related to defense except tactics and doctrine. The Research and Development Bureau of the Joint Chiefs of Staff (JCS) controls ADD by providing funds and assigning research tasks. There is no capability or function to process technological information in this bureau.

The Defense Industry Bureau in the Ministry of National Defense deals with contract administration, negotiation, and financing for acquisition. It is not a technology-related office.

Obviously it is necessary to activate an office or agency similar to the scientific and Technological Information Analysis Center (Figure 9). The primary mission of the agency is to link the sources and potential users of the technological information. The secondary mission is to analyze the status of the objective enterprise firm so as to find potential users. The functions of this agency would be collection, selection and storage of information, producing new information through retrieval processes, suggesting the potential users, and dissemination through appropriate channels.

According to the characteristics of these functions, this agency should be at a higher level in the hierarchy of the defense establishment so that the agency can directly contact foreign countries as well as other ministries and agencies of the government.

The infrastructure of this agency would be composed of specialists in each field of science and technology, military specialists, business management specialists, and computer and information systems specialists.

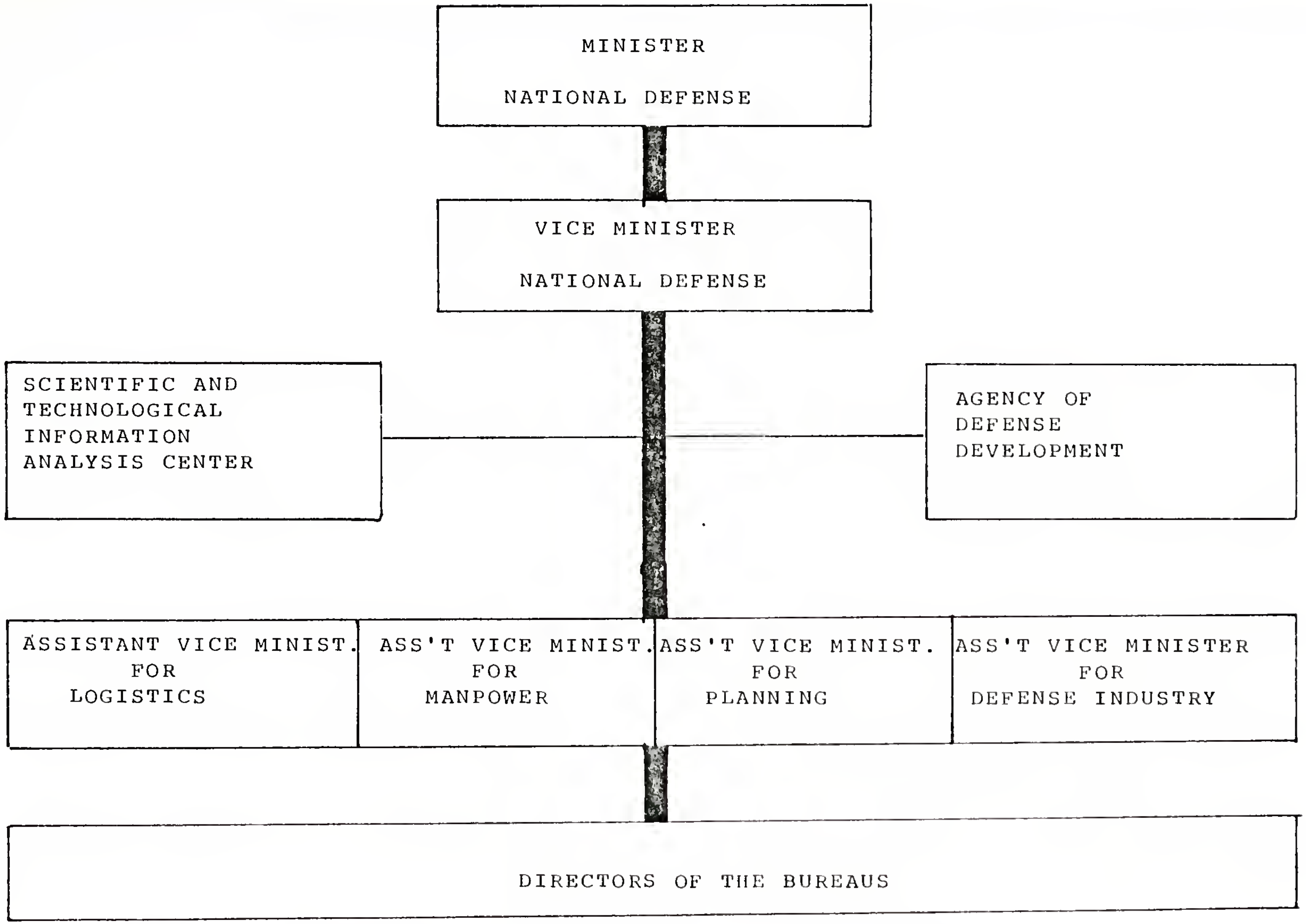

Figure 14 : Suggested position of Scientific and Technological Information Analysis Center in the Ministry of National Defense.

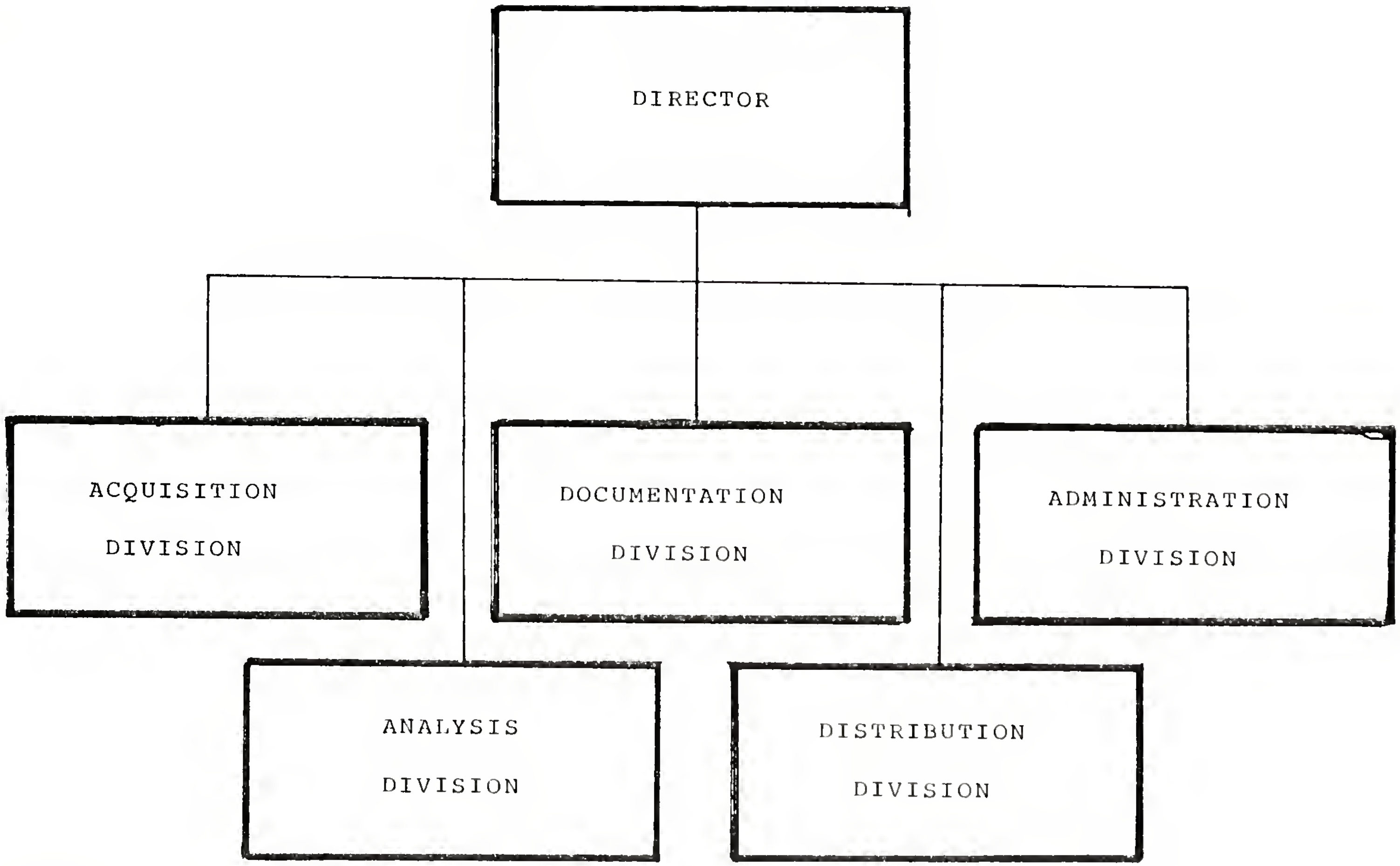

Figure 15 : Suggested Organizational Structure of Scientific and Technological Information Analysis Center.

IV. FINDINGS AND CONCLUSIONS

Korea, one of the countries most recently opened to the modern world, has grown as a new developing nation in terms of economic and military strength.

Through ambitious plans and strong implementation, Korea has achieved a high rate of economic growth during the past two decades. But there are many problems to be solved in order to continue steady growth. The most important and principal problem is lack of a technological base.

As history has shown, Korea has had its trials and survived among the big powers around the Korean Peninsula. Liberation and the consequences divided this highly complementary industrial structure in two, the North and the South. The Korean War was a turn for the worse. Social, political and economical chaos continued until the military coup in 1961. Colonial rule and foreign aid did not leave a technological inheritance.

The Korean military has gone through the same growth path as the economy. The armed forces, which are maintained with foreign assistance, lack the capability for self-reliance.

For both the economy and national defense, advanced technology is essential for self-reliance. The economy and national defense have responsibilities to support each other. The economy has the responsibility to finance the military while being protected by the military. The military has converse responsibilities.

To fulfill its responsibility, the Korean military must utilize its advantageous position. The Korean military has another responsibility to its allies who have helped to assure Korea's security. To achieve a high level of self-sufficiency in defense is necessary for the Korean military. To do so, technological innovation is required. And technological innovation can be accelerated by proper technology transfer processes.

Unfortunately, there are no appropriate activities for technology transfer in the Korean military establishment. As the term "technology transfer" means, there must be considerable activity to accelerate and guide the flow of technology in the intended direction. For this reason, the Korean Military Authority, the Ministry of National Defense, should establish and activate an office or agency which will take the role of Linker (in one sense, a catalyst) in the technology transfer process.

The primary mission of the agency would be to link the source and potential user of the technological information. And the secondary mission would be to analyze the status of the objective enterprise firm so as to find potential users.

The functions of this agency would be collection, selection and storage of information, producing new information through retrieval processes, suggesting the potential user, and dissemination.

The agency must be positioned at a higher level in the hierarchy of the defense establishment and be composed of all the area's specialists.

V. RECOMMENDATIONS

According to the conclusions, it is recommended to establish and activate an agency, tentatively named the Scientific and Technological Information Analysis Center, directly under the Vice Minister of National Defense.

The primary mission of the agency is to link the sources and potential users of the technological information. The secondary mission is to analyze the status of the objective enterprise firm so as to find potential users.

The functions of this agency are to collect, select and store the information, retrieve and produce new information, suggest the potential users, and disseminate information.

To perform these missions and functions, this agency will be composed of specialists in each field of science, technology, military, business management, and the computerized information system.

APPENDIX A

Federal Outlays for Research and Development, by Agency,
Fiscal Year 1977
(estimated, millions of dollars)

[Ref. 58, pp. 67, 68]

Agency and Subdivision	Outlay
Total, All Agencies	23,595.9
Departments	
Department of Agriculture, Total	518.6
Agricultural Research Service	282.9
Cooperative State Research Service	123.8
Economic Research Service	25.0
Farmer Cooperative Service	1.3
Forest Service	83.6
National Agricultural Library	*
Statistical Reporting Service	2.0
Department of Commerce, Total	230.1
Bureau of the Census	1.3
Economic Development Administration	11.9
Maritime Administration	19.2
National Bureau of Standards	50.4
National Fire Prevention and Control Administration	4.2
National Oceanic and Atmospheric Administration	139.6
Office of Minotiry Business Enterprise	1.9
Office of Telecommunications	1.2
Patent and Trademark Office	.4
Department of Defense, Total	10,969.0
Department of the Army	2,405.7
Military Functions	2,390.6
RDT&E Appropriations	2,287.0
Pay and Allowance of Military Personnel in R&D	92.1
Military Construction	11.5
Civil Functions	15.0

Department of the Navy- - - - - - - - - - - - - -	4,118.5
RDT&E Appropriations- - - - - - - - - - - - - -	4,007.0
Pay and Allowances of Military Personnel in R&D- - - - - - - - - - - - - -	97.0
Military Construction - - - - - - - - - - - - -	11.4
Special Foreign Currency Program- - - - - - -	3.1
Department of the Air Force - - - - - - - - - - -	3,740.3
RDT&E Appropriations- - - - - - - - - - - - - -	3,448.0
Pay and Allowances of Military Personnel in R&D- - - - - - - - - - - - - -	240.1
Military Construction - - - - - - - - - - - - -	52.2
Defense Agencies- - - - - - - - - - - - - - - - -	677.2
RDT&E Appropriations- - - - - - - - - - - - - -	669.8
Pay and Allowances of Military Personnel in R&D- - - - - - - - - - - - - -	7.3
Military Construction - - - - - - - - - - - - -	.2
Department-wide Funds - - - - - - - - - - - - - -	1.0
Director of Test and Evaluation, Defense- - - -	26.3
Department of Health, Education and Welfare, Total -	2,558.6
Alcohol, Drug Abuse and Mental Health Administration - - - - - - - - - - -	129.4
Center for Disease Control- - - - - - - - - -	40.1
Food and Drug Administration- - - - - - - - -	30.0
Health Resources Administration - - - - - - -	29.9
Health Services Administration- - - - - - - -	14.9
National Institute of Education - - - - - - -	88.0
National Institute of Health- - - - - - - - -	2,010.0
Office of Education - - - - - - - - - - - - -	77.7
Office of Human Development - - - - - - - - -	63.4
Office of the Assistant Secretary of Education- - - - - - - - - - - - - - - - -	11.1
Office of the Secretary - - - - - - - - - - -	29.6
Social and Rehabilitation Service - - - - - -	9.2
Social Security Administration- - - - - - - -	25.2
Department of Housing and Urban Development - - -	73.8
Department of the Interior, Total - - - - - - - -	308.1
Bonneville Power Administration - - - - - - -	4.7
Bureau of Land Management - - - - - - - - - -	1.0
Bureau of Mines - - - - - - - - - - - - - - -	129.1

Bureau of Outdoor Recreation	*
Bureau of Reclamation	8.2
Geological Survey	114.8
National Park Service	9.6
Office of the Secretary	1.5
Office of Water Research and Technology	18.2
United States Fish and Wildlife Service	21.0
Department of Justice, Total	42.9
Bureau of Prisons	1.8
Drug Enforcement Administration	3.6
Federal Bureau of Investigation	.6
Immigration and Naturalization Service	.4
Law Enforcement Assistance Administration	36.6
Department of Labor, Total	34.2
Bureau of Labor Statistics	1.7
Employment and Training Administration	15.8
Employment Standards Administration	5.5
Labor-Management Services Administration	2.8
Occupation Safety and Health Administration	6.3
Office of the Secretary	2.2
Department of State, Total	26.6
Departmental Funds	1.5
Agency for International Development	25.0
Department of Transportation, Total	347.5
Federal Aviation Administration	109.9
Federal Highway Administration	42.8
Federal Railroad Administration	41.8
National Highway Traffic Safety Administration	40.8
Office of the Secretary	29.1
United States Coast Guard	18.5
Urban Mass Transportation Administration	64.6
Department of the Treasury, Total	1.6
Bureau of Engraving and Printing	1.6
Other Agencies	
Action	*
Advisory Commission on Intergovernmental Relations	1.4
Civil Aeronautics Board	.5
Civil Service Commission	3.9
Community Services Administration	39.0

Consumer Product Safety Commission- - - - - - - - - -	6.4
Energy Research and Development Administration- - -	3,479.5
Environmental Protection Agency - - - - - - - - - - -	303.0
Federal Communications Commission - - - - - - - - - -	1.6
Federal Energy Administration - - - - - - - - - - - -	5.6
Federal Home Loan Bank Board- - - - - - - - - - - - -	.8
Federal Trade Commission- - - - - - - - - - - - - - -	1.3
Federal Services Administration - - - - - - - - - - -	2.8
Library of Congress - - - - - - - - - - - - - - - - -	3.4
National Aeronautics and Space Administration - - -	3,676.0
Nuclear Regulatory Commission - - - - - - - - - - - -	106.5
Office of Telecommunications Policy - - - - - - - -	2.7
Small Business Administration - - - - - - - - - - - -	.6
Smithsonian Institution - - - - - - - - - - - - - - -	31.6
Special Action Office for Drug Abuse Prevention - -	*
Tennessee Valley Authority- - - - - - - - - - - - - -	31.0
United States Arms Control and Disarmament Agency -	2.3
United States Information Agency- - - - - - - - - -	.1
Veterans Administration - - - - - - - - - - - - - - -	105.2

* Indicates amount less than $50,000.

APPENDIX B

AREAS OF FEDERAL RESEARCH AND DEVELOPMENT

[Ref. 59, pp. 1035-44]

AERONAUTICS

Aerodynamics: Operational flight characteristics and problems of fullscale aircraft as they are affected by the dynamics of air.

Aeronautics: Aircraft operations such as takeoff and landing, air traffic, all-weather and night flight, flight safety, and ground safety.

Aircraft: Design, production, and maintenance of aircraft, aircraft components, and aircraft equipment. Includes lighter-than-air craft, gliders, rotating-wing aircraft, and ground effect machines. Structural studies of complete aircraft parts such as airframes, bodies, wings, etc. Stability and control systems, boundary layer control systems, dynamic and static control devices. Aircraft damage assessment and vulnerability studies; effects of gunfire and blast on aircraft and flight equipment.

Aircraft Flight Instrumentation: Instruments necessary for controlling the flight of an aircraft. Includes artificial horizon, airspeed indicator, altimeter, etc.

Air Facilities: Airports, runways, hangars, control towers, ground refueling systems, aircraft handling and maintenance equipment.

AGRICULTURE

Agricultural Chemistry: The application of chemistry to the production and use of crops and livestock; chemurgy, fertilizers, feeds.

Agricultural Economics: Economic conditions, markets, production controls, subsidies, etc. affecting agriculture.

Agricultural Engineering: Design of farm machinery and farm structures. Soil conservation, water consdrvation, and irrigation. Processing of farm products.

Agronomy and Horticulture: Field crop production, cultivation of orchards, gardens, nurseries, etc. For plant anatomy, physiology, etc.

Animal Husbandry: Production and care of domestic animals, such as bovines, sheep, goats, horses, and swine; domestic animals used as pets. Includes veterinary medicine.

Forestry: Development, management, and cultivation of forests.

ASTRONOMY AND ASTROPHYSICS

Astronomy: Observation of celestial bodies, their distances, positions, etc.

Astrophysics: Physical and chemical aspects of celestial bodies, their origin and evolution. Includes astronomical spectroscopy and radio astronomy.

Celestial Mechanics: The motions of celestial bodies under the influence of gravity.

ATMOSPHERIC SCIENCES

Atmospheric Physics: Physical and chemical properties of the atmosphere, exclusive of considerations of weather and climate, Aeronomy, aurora and airglow, atmospheric structure, energetic particles, solar-terrestrial relationships, etc.

Meteorology: Weather observation, prediction, and modification, climatology.

BEHAVIORAL AND SOCIAL SCIENCES

Administration and Management: Accounting, planning, budgeting, operations, public relations, production planning, organization coordination, etc.

Documentation and Information Technology: Library science: acquisition, cataloging, indexing, abstracting, bibliography. Information storage and retrieval systems.

Economics: Econometrics, economic history, economic theory, banking and finance, international economic relations, trade and commerce.

History, Law, and Political Science: Theory and practice of government, international relations, politics, law, etc.

Human Factors Engineering: Design of equipment with emphasis on optimum utilization by humans. Habitability of work and living space.

Humanities: Philosophy, literature, art, music, drama, etc.

Linguistics: Study of languages, including phonology, morphology, syntax, and semantics. Mathematical linguistics. Machine translation.

Man-Machine Relations: Interaction of man and equipment in terms of subsystem and system performance requirements and evaluation. Encompasses manual controls, information displays. Information processing, tactical kinethesis and other human sensory modalities involved in operation of equipment and understanding of personnel subsystems.

Personnel Selection, Training, and Evaluation: Recruitment, selection, training, and utilization of personnel. Industrial relations, wages, benefits. Education, teaching aids, teaching methods. Job analysis, career guidance.

Psychology (Individual and Group Behavior): Mental processes and phenomena such as perception, learning motivation, intelligence, attitudes, group dynamics, etc. Experimental psychology, including animal behavior; physiological psychology; developmental psychology; social psychology; clinical psychology; educational psychology; military psychology; and parapsychology.

Sociology: Social relations, the functioning of human society, ethnology, criminology, etc.

BIOLOGICAL AND MEDICAL SCIENCES

Biochemistry: Studies of the chemical processes which take place in biological systems. Identification of biochemical substances and the methods used for biochemical assay and analysis.

Bioengineering: Establishment of requirements for, and development of, bioinstrumentation and equipment needed by man in operation of man-machine systems. Includes instrumentation for psychophysiological monitoring and biomedical information handling. Compact, lightweight transducers and transmitter equipment introducing minimum constraint of subject. Man's requirements for displays and controls. Use of body potentials as intrinsic power supplies.

Biology: Biological topics not included in other Groups, e.g., botany, zoology, genetics, etc. Animal anatomy, physiology, and pathology. Care and breeding of laboratory animals.

Bionics: Study of biological processes in order to develop engineering systems.

Clinical Medicine: General medicine, medical specialties, and paramedical sciences. Internal medicine, including

preventative medicine; pediatrics and geriatrics; dermatology, ophthalmology; psychiatry; dentistry. Includes nursing, first aid, medical technology, physical therapy, and prosthesis.

Environmental Biology: External influences on the biological processes of organism. Ecology, pesticides, insect vectors, pest control, natural noxious agents, etc.

Escape, Rescue, and Survival: Methods and equipment for escape from disabled aircraft, submarines, etc. Rescue equipment, signals, flotation devices, survival kits.

Food: Processing, packing, storage, preparation, and dispensing of food. Kitchen equipment.

Hygiene and Sanitation: Personal hygiene

Industrial (Occupation) Medicine: Interaction of man and industrial environment. Noise, physical trauma, etc.

Life Support: Equipment and techniques for sustaining life in environments where normal respiration is not possible. Systems which provide, as a mininum, respiratory support. Includes closed ecological systems, space suits, diving gear, oxygen masks, etc.

Medical and Hospital Equipment and Supplies: Equipment and supplies for laboratory and field use.

Microbiology: Studies of microscopic plants and animals.

Personnel Selection and Maintenance (Medical): Physical standards, examinations, anthropometrics, physical fitness.

Pharmacology: The synthesis, composition, properties, and physiological effects of drugs. Includes psychopharmacology.

Physiology: Organic processes and pehnomena of humans, e.g., growth, aging, metabolism, biological rhythm, healing and repair, sensation, etc. Human anatomy.

Protective Equipment: Equipment providing protection against such environmental elements as heat, cold, noise, machinery, etc.

Radiobiology: Radiation biology. Interaction of biological systems with electromagnetic and particle radiation. Dosimetry, health physics, radiation injury. Prophylaxis and therapy of nuclear radiation sickness and injury.

Stress Physiology: Effects of extreme environments or unusual stimulation on biological processes. Physiological

effects of motion, gravity, sound, light, heat, magnetism, sensory deprivation, fatigue, etc.

Toxicology: Detection, neutralization, decontamination, physiological effecte, etc. of poisonous substances.

Weapon Effects: Wounds, injuries, or other medical conditions directly resulting from weapons.

CHEMISTRY

Chemical Engineering: Techniques, processes, unit operations, apparatus, and plant equipment that apply to chemical manufacturing, processing, transportation, and storage.

Inorganic Chemistry: Synthesis, properties, and reactions of inorganic compounds; studies of the elements; inorganic quantitative and qualitative analysis.

Organic Chemistry: Synthesis, properties, and reactions of organic compounds; organic quantitative and qualitative analysis.

Physical Chemistry: Physical aspects and theoretical interpretations of chemical systems. Collois chemistry, catalysis, solutions, chemical equilibria and reaction kinetics, surface chemistry, chemical thermodynamics and thermochemistry, etc. Physical methods of analysis not applied exclusively to either organic or inorganic chemical substances. Atomic and molecular structure and spectra; spectroscopic analysis for the fundamental understanding of chemical bonding, nuclear motions, etc. Nuclear magnetic resonance spectroscopy and electron paramagnetic resonance spectroscopy.

Radio and Radiation Chemistry: Chemistry of the effects of electromagnetic and particle radiation on matter. Chemistry of radioactive substances. Tracer studies. Includes photochemistry.

EARTH SCIENCES AND OCEANOGRAPHY

Biological Oceanography: Marine plant and animal life as it relates to its environment.

Cartography: Mapping, photogrammetry, terrain models, etc.

Dynamic Oceanography: Ocean waves, currents, tides, ocean-air interactions, etc.

Geochemistry: Chemical composition of the earth's crust.

Geodesy: Geodetic surveying. Determination of position of points on the earth's surface. Shape and size of the earth. Variations of terrestrial gravity.

Geography: Description of the physical features of the earth, the distribution of plants and animals. Includes political, economic, and commercial geography.

Geology and Mineralogy: Structure, properties, and classification of rocks, rock formations, and rock constituents. Mineraolgy, paleontology, stratigraphy.

Hydrology and Limnology: Properties, distribution, and circulation of water, including its surface and underground occurrence. Physical, chemical, and biological conditions in fresh water bodies.

Mining and Engineering: Location and evaluation of mineral deposits. Layout and equipment of mines. Mining operations.

Physical Oceanography: Physical and chemical properties of ocean water. Topography and composition of the ocean bottom.

Seismology: Detection, measurement, and recording of seismic phenomena.

Snow, Ice, and Permafrost: Physical characteristics of snow, ice and permanently frozen soil.

Soil Mechanics: Physical properties and engineering aspects of soils.

Terrestrial Magnetism: Geomagnetic variations, field theory, magnetic moments, etc.

ELECTRONICS AND ELECTRICAL ENGINEERING

Components: Design and development of basic electrical and electronic components such as electron tubes, semiconductor devices, switches, connectors, etc.

Computers: Design, development, and application of electronic computers and peripheral equipment. Includes analog, digital analog-digital, special purpose, and general purpose computers; computer accessories, supplies and installation; computer software such as programs, programming languages, program generators, compilers, executive routines. and system evaluation.

Electronic and Electrical Engineering: Electronic systems, except those included in Navigation, Communications, Detection, and Counter-measures. Electrical systems.

Information Theory: Representation, uncertainty, noise, information content, information entropy, coding theory.

Subsystems: Electrical and electronic devices which are composed of components, but which require other such devices to form complete systems. Includes amplifiers, antennas, etc.

Telemetry: Techniques and equipment, including transmitters, receivers, antennas, etc.

ENERGY CONVERSION (NON-PROPULSIVE)

Conversion Techniques: Techniques and devices for the conversion of one form of energy to a form of non-electrical energy, but which do not primarily involve energy storage.

Power Sources: Devices which supply electric power by energy conversion processes which do not primarily involve energy storage. Includes generators, converters, fuel cells, etc.

Energy Storage: Techniques and devices for the storage and subsequent use of energy. Includes electrical batteries and battery components.

MATERIALS

Adhesives and Seals: Adhesives, glues, binders, etc. for all types of materials. Sealants, seals, and gaskets.

Ceramics, Refractories, and Glasses: Ceramic materials, including glasses, brick, porcelain, tiles, etc. Non-metallic refractory materials. Cements.

Coatings, Colorants, and Finishes: Paints, paint primers, varnishes. Plastic, rubber, ceramic, and metal coatings. Uses of dyes and pigments.

Composite Materials. Materials composed of two or more physically distinct constituents.

Fibers and Textiles: Natural and synthetic fibers, threads, yarns, and textiles.

Metallurgy and Metallography: Refining and production of metals and alloys. Microstructure, physical and mechanical properties, corrosion studies, etc. Heat-resistant metals and alloys. Includes extractive and physical metallurgy.

Miscellaneous Materials: Materials not included in another Group, including leather, fur, and other animal products. Refrigerants, straw, waxes, etc.

Oils, Lubricants, and Hydraulic Fluids: Properties, performance, and production of all types of oils, lubricants, and hydraulic fluids.

Plastics: Properties, performance, and production of all types of plastics and resins, including reinforced plastics and laminates.

Rubbers: Production, performance, and properties of natural and synthetic rubber and rubber products. Elastomers.

Solvents, Cleaners and Abrasives: Cleaning compositions, solvents, detergents, soaps, abrasives, etc.

Wood and Paper Products: Wood, wood products, paper, cardboard, etc.

MATHEMATICAL SCIENCES

Mathematics and Statistics: Mathematics and statistics research.

Operations Research: Theoretical operations research.

MECHANICAL, INDUSTRIAL, CIVIL, AND MARINE ENGINEERING

Air Conditioning, Heating, Lighting, and Ventilating: Air conditioning systems, refrigeration systems, cold storage systems. Heating systems, heat pumps, boilers, furnaces, radiators, condensers. Lighting systems.

Civil Engineering: Water supply systems: well drilling, water collection, storage, treatment, distribution. Sanitary engineering: waste and sewage disposal, air and water pollution control. Flood control. Highway and traffic engineering. Urban planning and renewal.

Construction Equipment, Materials and Supplies: Excavation and earth moving equipment, hoisting and conveying equipment, construction equipment. Building materials and supplies.

Containers and Packaging: Design, production, performance, and testing of containers. Packaging methods. Storage tanks and accessories.

Couplings, Fasteners, and Joints: Design, performance, and testing of bolts, screws, studs, rivets, hooks, couplings, and fittings. Bonded, soldered, and welded joints, etc.

Ground Transportation Equipment: Design, operation, performance, and maintenance of amphibious vehicles, cargo vehicles, passenger vehicles, automotive parts and equipment, and railroad equipment.

Hydraulic and Pneumatic Equipment: Design, production, performance, and testing of hydraulic and pneumatic systems. Accumulators, distribution equipment, actuators, controls, and components.

Industrial Processes: Production control, quality control, plant design, inspection. Fabrication, cleaning and finishing, etc. of industrial materials. Includes fabrication metallurgy: casting, forging, drawing, eledtroforming, extrusion, machining, rolling, stamping, spinning, welding.

Machinery and Tools: Machines and machine elements, including bearings, clutches, drives, gears, cam, springs, etc. Metalworking tools, woodworking tools, dies, jigs, etc.

Marine Engineering: Design, construction, maintenance, salvage, operation, and performance of all types of ships, boats, and marine equipment.

Submarine Engineering: Design, construction, maintenance, salvage, operation, and performance of submarines and submarine equipment.

Pumps, Filters, Pipes, Tubing and Valves: Design, construction, operation and performance of all types of pumps, filters, pipes and pipe fittings and valves.

Safety Engineering: Accident prevention, safety devices, fire-fighting equipment, fire-detection equipment.

Structural Engineering: Design and construction of structures such as buildings, bridges, dams, etc.

METHODS AND EQUIPMENT

Cost Effectiveness: Examination and selection of equipment, materials, personnel, etc. for optimum performance of given tasks. Cost-benefit analysis, tradeoff factors, etc.

Laboratories, Test Facilities, and Test Equipment: Laboratory and test facility design and operation. Measuring, testing, and simulation devices with apparent application in more than one group.

Recording Devices: Techniques and devices for electrical recording. Includes disk, magnetic, electrostatic, etc.

Reliability: Determination of the probability of satisfactory performance of components and equipment. Prevention and correction of malfunctions.

Reprography: Photographic techniques, equipment, and materials. Reproduction techniques. Printing and graphic arts.

MILITARY SCIENCES

Antisubmarine Warfare: Operations conducted against submarines.

Chemical, Biological, and Radiological Warfare: Development and utilization of lethal and non-lethal chemical agents, biological agents, and radiological weapons. Detection, decontamination, protective equipment, etc. CBR ordnance items, such as bombs, projectiles, and rockets.

Defense: Active and passive systems for military and civil defense. Antiaircraft and antisatellite defense systems.

Antimissile Defense: Techniques and equipment for the interception and desctuction of guided missiles.

Intelligence: Techniques for collecting, evaluating, and disseminating information concerning foreign nations needed for purposes of national security.

Logistics: Procurement, storage, distribution, and reclamation of equipment and supplies. Design and testing of personal equipment, such as clothing, field gear, etc. Transportation. Industrial mobilization.

Nuclear Warfare: Development and utilization of nuclear weapons. Studies of the physics and physiological effects of nuclear weapons.

Operations, Stretegy, and Tactics: Joint and combined operations. Campaigns, battles, invasions, theater operations, etc. Methods of attack and support. Types of warfare.

MISSILE TECHNOLOGY

Missile Launching and Ground Support: Missile handling and launching, including transportation; storage; preparation for launching; surface, aircraft, or underwater launching. Launching equipment, checkout equipment, and ground support equipment.

Missile Trajectories: Determination, analysis, and processing of missile trajectory data. Flight path analysis, impact prediction, etc. Operational aerodynamic studies, including reentry.

Missile Warheads anf Fuzes: Design and performance of all warhead types, including explosive, chemical, biological, and nuclear missile fuzes of all types.

Missiles: General missile theory, design, construction, performance and components. Damage assessment and vulnerability studies.

Air- and Space-Launched Missiles: Theory, design, construction, performance, and components. Damage assessment and vulnerability studies.

Surface-Launched Missiles: Theory, design, construction, performance, and components. Damage assessment and vulnerability studies.

Underwater-Launched Missiles: Theory, design, construction, performance, and components. Damage assessment and vulnerability studies.

NAVIGATION, COMMUNICATIONS, DETECTION AND COUNTERMEASURES

Acoustic Detection: Detection by means of acoustic waves, including ultrasonic and infrasonic radiation.

Communications: Communications by wire or electromagnetic waves other than radio waves.

Radio Communications: Communications by radio waves.

Direction Finding: Determination of the direction of arrival of signals.

Electromagnetic and Acoustic Countermeasures: Interception, jamming and antijamming, and deception of acoustic and electromagnetic signals.

Infrared and Ultraviolet Detection: Detection by measurement of infrared and ultraviolet radiation.

Magnetic Detection: Detection by measurement of a magnetic field.

Navigation and Guidance: Techniques for navigation and guidance. Includes air traffic control systems, controlled-approach systems, and instrument landing systems.

Optical Detection: Detection by means of light. Includes such optical instruments as binoculars and periscopes.

Radar Detection: Detection by means of transmitted and reflected radiofrequency waves.

Seismic Detection: Detection by measurement of seismic waves.

NUCLEAR SCIENCE AND TECHNOLOGY

Fusion Devices (Thermonuclear): Theory, design, construction, and operation of devices for producing controlled thermonuclear fusion reactions.

Isotopes: Separation or concentration of isotopes. Industrial and medical applications.

Nuclear Explosions: Explosion effects such as shock waves and earth movement. Testing of nuclear devices. Peaceful applications, such as Plowshare.

Nuclear Instrumentation: Radiation detection devices and associated equipment.

Nuclear Power Plants: Integrated assemblage, including reactor and turbogenerator equipment, plus control and regulatory devices. Includes mobile as well as stationary power plants.

Radiation Shielding and Protection: Shielding design, isodose plots, materials transmission and absorption studies, safety devices, decontamination, etc.

Radioactive Wastes and Fission Products: Separation, processing, handling, storage, and disposal. Fission product utilization.

Radioactivity: Radioactive decay, natural and induced radioactivity, interaction of charged particles and radiation with a-tter, radioactive fallout.

Reactor Engineering and Operations: Engineering related directly to the design or operation of a specific reactor or reactor type.

Reactor Materials: Production, testing, or reclamation of fuel materials, coolants, moderators, control materials, structural materials, and shielding materials. Includes fabricated elements or assemblies and specific configurations.

Reactor Physics: Reactor kinetics, reactor theory, criticality and neutron thermalization, scattering, slowing down economy, etc. Includes the use of reactor simulators or computers.

Reactors (Power): Design, construction, operation, etc., of reactors used as energy sources for electric power generation.

Reactors (Non-Power): Reactors designed and built for purposes other than for electric power or propulsion. Includes production research and training, test, and process heat types.

SNAP Technology: Systems for Nuclear Auxiliary Power, both isotopic and reactor.

ORDNANCE

Ammunition, Explosives, and Pyrotechnics: Projectiles, fuzes, demolition explosives, detonators, grenades, land mines, high explosives, primers, powder propellants, ammunition shaped charges, flame throwers, ammunition handling equipment, etc. Production, performance, stability in storage, etc. of incendiaries, pyrotechnics, screening agents and smokes, etc.

Bombs: High-explosive, fragmentation, anti-personnel, armor-piercing, general-purpose, etc. Bomb handling equipment.

Combat Vehicles: Armored wheeled and track-laying vehicles for both cargo and personnel. Heavy, light, and medium tanks. Tank chassis used as gun carriers, their components and accessories.

Explosions, Ballistics, and Armor: Explosion effects such as blast, heat, earth movement, etc. Ballistics. Armor plate, body armor, etc.

Fire Control and Bombing Systems: Computers, sights, directors, range finders, gun-laying and bombing radar systems, bomb releases and other devices used to direct the firing of a weapon.

Guns: Small arms, automatic weapons, recoilless weapons, mortars, artillery and naval guns, their components, accessories, and interior ballistics. Gun carriages, gun mounts, remote control equipment, etc.

Rockets: Rocket-propelled weapons, including aircraft, large caliber, and shoulder-fired rockets. Launching devices.

Underwater Ordnance: Torpedoes, submarine mines, depth charges, hydrobombs, etc. Launching devices and countermeasures.

PHYSICS

Acoustics: Generation and propagation of acoustic waves, including ultrasonic and infrasonic radiation.

Crystallography: Structure and properties of crystalline forms.

Electricity and Magnetism: Theory of electrical and magnetic phenomena.

Fluid Mechanics: Theoretical and experimental studies of the dynamics and statics of fluids, including aerodynamics and hydrodynamics.

Masers and Lasers: Devices which amplify electromagnetic waves by stimulated emission of radiation. Includes irasers, uvasers, etc.

Optics: Generation and propagation of electromagnetic waves in infrared, visible, and ultraviolet regions of the spectrum. Techniques and design of optical equipment for mass spectroscopy.

Particle Accelerators: Design and operation of betatrons, cyclotrons, synchrotrons, etc.

Particle Physics: Properties and reactions of elementary particles. Nuclear reactions. Gamma rays, x-rays.

Plasma Physics: Properties of actions of plasmas, including magnetohydrodynamics, pinch effect, plasma oscillations, plasma jets, etc.

Quantum Theory: Relativistic and nonrelativistic quantum theory, relativity theory, quantum mechanics and quantum statistics.

Solid Mechanics: Dynamics and statics of solid bodies. Structural mechanics, kinetics, kinematics, equilibria, stress analysis, buckling, elasticity, plasticity, vibrations, shock and vibtation, etc.

Solid State Physics: Structure and properties of solids. Properties of solids at cryogenic temperatures. Includes fundamental research and theoretical studies of semiconductors.

Thermodynamics: Thermodynamic theory; equations of state, free energy, enthalpy, entropy, thermodynamic cycles, etc. Heat transfer, including methods for determining thermal radiation properties of materials. Low-temperature phenomena.

Wave propagation: Propagation of radiofrequency waves. Includes microwave optics.

PROPULSION AND FUELS

Air Breathing Engines: Advanced engines which use ingested air to oxidize their fuel, e.g., the liquid air cycle engine (LACE).

Combustion and Ignition: Combustion and flame studies. Ignition and ignition systems.

Electric Propulsion: All types of engines deriving power from free ions or electrons. Ion, plasma, and arc-jet engines.

Fuels: Production, performance, storage, etc. of all types of fuels except those used in rocket engines.

Jet and Gas Turbine Engines: All types of jet and gas turbine engines, including hydroduct, turboprop, etc.

Nuclear Propulsion: Nuclear devices for marine, ground, air, and space propulsion.

Reciprocating Engines: Reciprocating Engines of various configurations for all types of propulsion.

Rocket Motors and Engines: General studies of rocket motors and propulsion hardware. Gaseous, thixotropic, and hybrid rocket motors.

Liquid Rocket Motors: Studies of liquid rocket motors and propulsion hardware.

Solid Rocket Propellants: Production, handling, performance, etc. of all-solid rocket propellants, including fuels, oxidizers, additives, binders, etc.

SPACE TECHNOLOGY

Astronautics: Orbital rendezvous, space exploration, operations in space, spacecraft operating problems, etc.

Spacecraft: Design and construction of spacecraft, including satellites, space probes, space capsules, spaceships, space stations, aerospace planes, and their components. Spacecraft damage assessment and vulnerability studies.

Spacecraft Trajectories and Reentry: Determination, analysis, processing, etc. of spacecraft trajectory data.

Orbital calculations, flight path analysis, reentry, space mechanics, etc.

Spacecraft Launch Vehicles and Ground Support: Handling and launching, including transportation, storage, preparation for launching, and countdown. Launching equipment, checkout equipment, and ground support equipment.

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